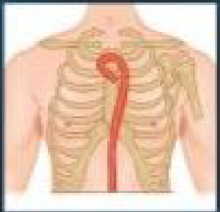
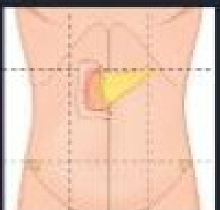
Surface and Radiological Anatomy

with a Clinical Perspective





Ashwini C Appaji
Roopa Kulkarni

Foreword
Sheela G Nayak

JAYPEE

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with a Clinical Perspective

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Foreword

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Dedicated to

Our Parents, In-laws, Husbands and Children
for their patience and co-operation during
the writing of this textbook.

Foreword

A sound knowledge of gross anatomy is invaluable for understanding Surface and Radiological Anatomy.

Though there is no dearth of material on Surface and Radiological Anatomy, I appreciate the commendable effort of the authors to collect and provide essentially relevant material with sketches and photographs in a concise and systematic manner. The clinical correlations have been mentioned in the colored boxes wherever necessary for the students of anatomy as well as clinical students. Each chapter in Surface Anatomy provides basic concept and information necessary to understand morphology of the structures intended to practice Surface Anatomy.

Recent advances in the field of Radiodiagnosis are overwhelming. The students get a glimpse of modern imaging techniques in addition to conventional radiography, so that they are aware of the importance of Cross-sectional Anatomy in Radiodiagnosis well before they enter into clinical side.

It is a simple and complete textbook providing an overview of the subject for quick recall, which fulfills the needs of the present generation of students.

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Preface

Medicine is more an art than science in the hands of a skilled physician. But the fact is that the art is fast vanishing with the advent of evolving technology, which has put more diagnostic tools into the physicians' bags. Bedside medicine needs revival so that the patient does not have to go through unnecessary tests and also waste time and money. The need of the hour is to bring back these clinical skills in our students and we, the authors of this book, see Surface Anatomy as the first step towards this goal.

Gross Anatomy is the most basic and relatively constant of all basic medical sciences. The basic human structure remains the same, though many normal variations have been studied. Hence, thorough knowledge of anatomy is very important to build up our clinical skills and knowledge further.

This textbook is targeted at health professional students and also clinicians. The focus here is mainly on providing Surface Marking and Radiology of various internal organs and structures and also the surgical approach in certain situations. The book also carries the relevant Applied Anatomy, such as clinical findings in health and disease, various pathologies that can involve the structures, differential diagnoses, various surgical methods, etc. in separately highlighted boxes.

This textbook will be helpful to all health professional students in their clinical examinations and the clinicians in their daily practice.

A sincere effort has been made towards promoting the art of medicine. Suggestions from our readers regarding any improvements are always welcome.

Ashwini C Appaji
Roopa Kulkarni

Acknowledgments

We sincerely acknowledge **Dr MR Jayaram**, Chairman, MS Ramaiah Medical College, and Gokula Education Foundation, Bengaluru, Karnataka, India for all our professional achievements and thank him for giving us this platform to think of such a textbook.

We are grateful to **Dr DV Guruprasad**, Chief Executive, Gokula Education Foundation (Medical), who has been energetic and inspiring for all our academic works.

We are very thankful for the support of **Dr Ashok Kumar**, Professor and Head, Department of Radiology in providing us with good-quality radiograms.

We also acknowledge the contribution in clinical correlations of this textbook by **Dr Lakshmi M**, DNB (Internal Medicine), currently working as Senior Resident in the Department of General Medicine, Shri Ramachandra Medical College and Research Institute, Chennai, Tamil Nadu, India.

We are also grateful to **Dr Rashmi CR**, who is instrumental in bringing to our notice about the need of such a learning material.

We would like to thank **Mr Chethan N**, who volunteered for the photographs.

We would also like to thank **Shri Jitendar P Vij** (Group Chairman), **Mr Ankit Vij** (Group President), **Ms Chetna Malhotra Vohra** (Associate Director–Content Strategy), **Ms Payal Bharti** (Project Manager), and the production team of **Jaypee Brothers Medical Publishers** for their cooperation in completing this project flawlessly.

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Section 1

Surface Anatomy

CHAPTERS

1

Surface Anatomy with a Clinical Perspective

INTRODUCTION

Surface anatomy is defined as to outline the organs and important internal structures on the surface of the body. The surface anatomy is very much essential because the body cannot be opened everytime, a diagnosis of a disease needs to be done as to which organ is affected. Surface anatomy knowledge enables the clinician to assess the internal organs from the surface by clinical examination. Hence, surface anatomy though neglected has to be given more importance as it is widely used by the clinicians. The knowledge is useful during feeling of pulse, measurement of blood pressure, hearing heart and breathing sounds, identification of organomegaly, incision and drainage, aspirations like lumbar puncture and many more.

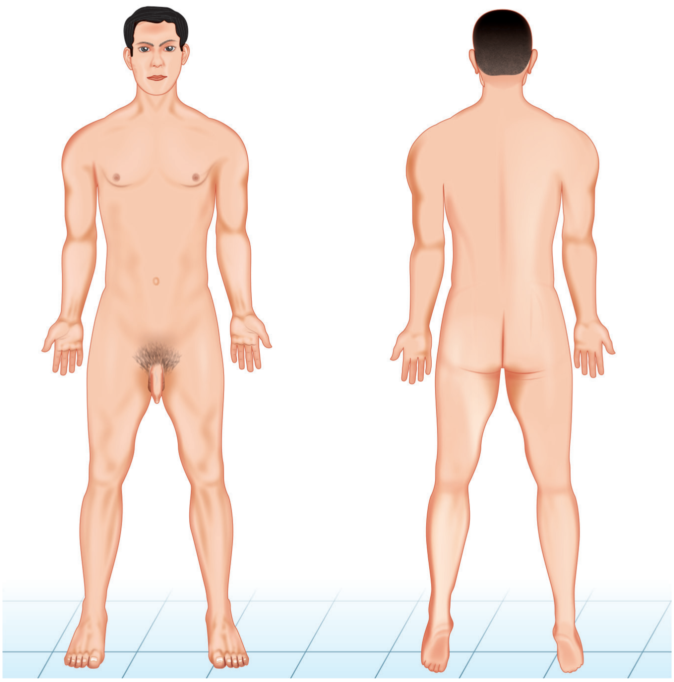

Fig. 1.1: Anatomical position of the human body.

Anatomical Position of the Human Body

This is described as the human body standing upright with the hands supinated and the feet resting on the ground completely. In this position, all the joints are in extended position and the eyes looking straight forward. The upper limbs are dropping down in adducted position as shown in Figure 1.1. The lower limbs are placed at 1-foot width with the toes directed forward.

Thus, the anatomical position is defined as **"body in erect posture, with upper limbs on the sides, with palms and feet directed forward and eyes directed toward the horizon"**.

The position is important to know as all the planes and imaginary lines are drawn in this anatomical position and used as universal reference.

The surface anatomy of every structure and organ is drawn on the surface of the human bodies keeping the anatomical position in mind.

There are **four main methods of clinical examination** of any organ system in general (except nervous system, which is different). These are as follows:

1. ***Inspection*:** Visual screening of the surface area concerned for the usual normal structures or to look for any visible abnormalities (e.g. abnormal swellings, dilated veins).
2. ***Palpation*:** Feeling for the underlying organ or abnormality (e.g. palpation for liver, spleen, palpation of any swellings on the limbs or the body).
3. ***Percussion*:** Percuss for any organ enlargement or pathology specifically on the surface of the thorax or abdomen (e.g. percussion of liver, gas or fluid in abdomen, heart borders).
4. ***Auscultation*:** Listen to normal physiological sounds or abnormal sounds with a stethoscope (e.g. heart sounds, lung sounds).

All these require a sound knowledge of surface anatomy, because as the saying goes "**the eyes can see only what the mind knows**".

Surface Anatomy of the Thorax

2

BONY AND SOFT TISSUE LANDMARKS (FIGS. 2.1 AND 2.2)

1. ***Suprasternal notch*:** This is felt at the superior border of the sternum.
2. ***Sternal angle*:** This is the joint between the manubrium sterni and the body of the sternum. This can be felt as a prominent ridge as we move from the suprasternal notch below over the manubrium sternum at the junction between manubrium and body of sternum. This joint also corresponds to the articulation of the 2nd costal cartilage to the sternum.
3. ***Counting of ribs*:** This can be initiated by identifying the manubriosternal angle as this corresponds to the 2nd rib. Then continue counting ribs downwards and laterally.
4. ***Costal margin*:** This is a continuous bony margin formed by the joining of the sternal end of the 7th to 10th ribs to one another via the costal cartilages.
5. ***Subcostal angle*:** This is the angulation between the two costal margins.

Applied Anatomy

Sternum is divided in the midline from the suprasternal notch and the xiphoid process for open heart procedures. This is called midline sternotomy.

For access to the trachea, the 3rd intercostal space is used and for the esophagus and lower lobes of the lung, the 5th to 7th intercostal space is used as a landmark.

6. ***Counting of ribs in the back*:** Feel for the spinous process of the 7th cervical vertebra (vertebra prominence). This is visible and palpable. Then start counting below. The third thoracic vertebra corresponds to the superior border of the scapula, 5th thoracic vertebra to the spinous process of the scapula and the 7th thoracic vertebra to the inferior angle of the scapula.
7. The suprasternal notch corresponds to the 2nd thoracic vertebra. The sternal angle corresponds to the 4th thoracic vertebra, the xiphisternal joint corresponds to the intervertebral disk between the 9th and the 10th vertebrae.
8. Few lines can be drawn with reference to the bony landmarks for the thorax. These lines are very useful during invasive procedures such as putting drainage insertion, anesthesia, needle decompression, etc. these include (Figs. 2.2A and B).
    a. ***Midsternal line*:** Line drawn through the middle of the sternum.
    b. ***Midclavicular line*:** Drawn through the midpoint of the medial and lateral end of the clavicle. This usually passes through the nipple.
    c. ***Anterior axillary line*:** This line is drawn vertically at the plane of anterior axillary fold.

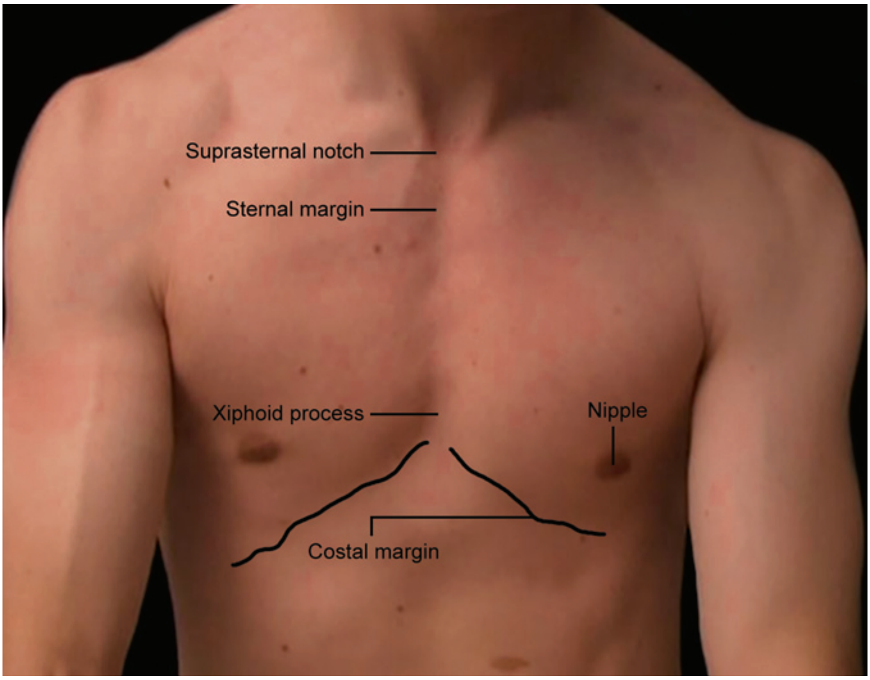

Fig. 2.1: Bony and soft tissue landmarks of the anterior thoracic wall.

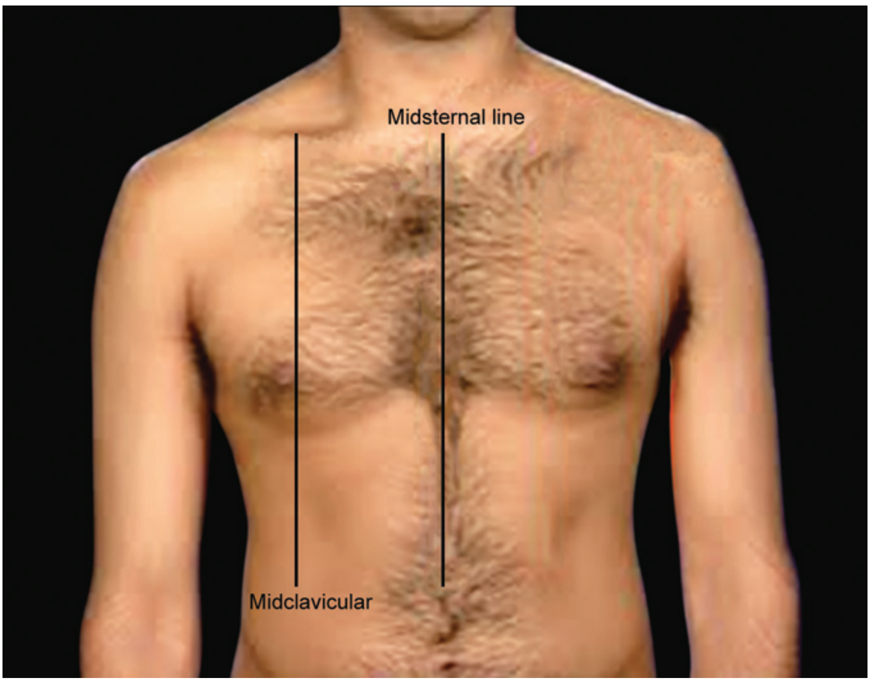

Fig. 2.2A: Imaginary lines on the anterior thoracic wall.

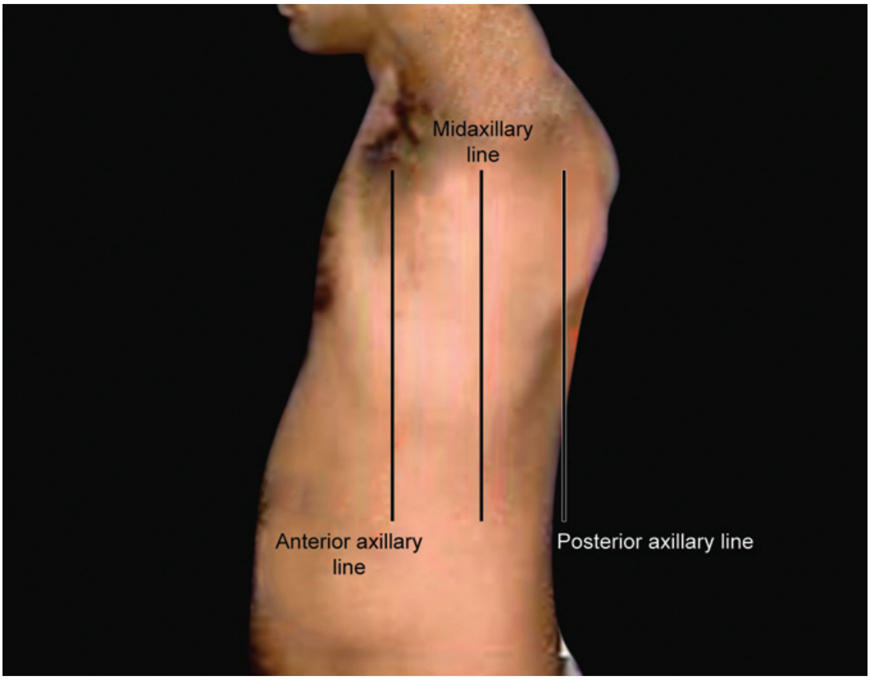

Fig. 2.2B: Bony landmarks of the lateral thoracic wall.

d. ***Posterior axillary line*:** This line is drawn at the plane of the posterior axillary fold.
e. ***Midaxillary line*:** passes from the apex of the axilla between the anterior and the posterior axillary folds.

Soft Tissue Landmarks (*see* Fig. 2.1)

1. ***Nipple*:** It is the projection of the breasts. It is dark due to pigmentation. This soft tissue is constant in position in males. It lies in the 4th intercostal space in the midclavicular line. The nipple is inconsistent in position in females because of the sagging breasts. It also depends on the size of the breasts.

Borders of the Heart (Fig. 2.3A)

The heart anatomically can be shown in four borders. They are the right, left, upper and lower margins. They can be drawn by identifying the following points.

***Point A*:** Marked on the right 3rd costal cartilage by the side of the right sternal margin.

***Point B*:** Marked on the left 2nd intercostal space by the side of the left sternal margin.

***Point C*:** Right 6th costal cartilage joining the sternum.

***Point D*:** Left 5th intercostal space just medial to the midclavicular line.

Upper border is formed by the joining of the points A and B.

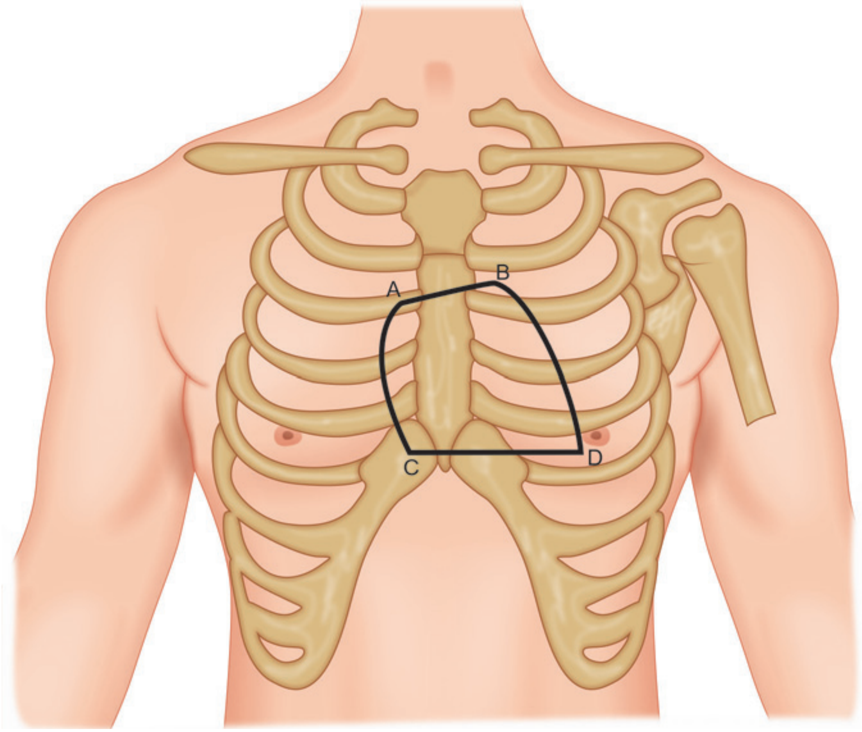

Fig. 2.3A: Borders of the heart.

Lower border is formed by the joining of the points C and D.

Right border is formed by the joining of the points A and C by a curved line. Convexity is maximum in the 4th intercostal space, about 3.7 cms to 4 cms from the midline. Left border is formed by the joining of the points B and D.

Anatomically right border represents the right atrium. The left border represents the left ventricle. The lower border represents the right ventricle. The upper border represents the left atrium.

Applied Anatomy

By drawing/identifying the borders of the heart, it is possible to percuss the borders and be able to identify the enlargement of the heart. This also helps in putting the leads of the electrocardiogram (ECG) and continuous cardiac monitoring.

The area bounded by the borders of the heart is called as the precordial area.

The apex of the heart and the right shoulder are in the same plane. When a line is drawn in the perpendicular plane, this represents the coronary sulcus or the atrioventricular groove. This groove lodges the coronary vessels. The plane differentiates the atria from the ventricles.

The sternocostal surface represents most of the right ventricle. The right atrium and the right ventricle are more anteriorly placed than the left atrium and left ventricle in a 3-dimensional orientation (Fig. 2.3B).

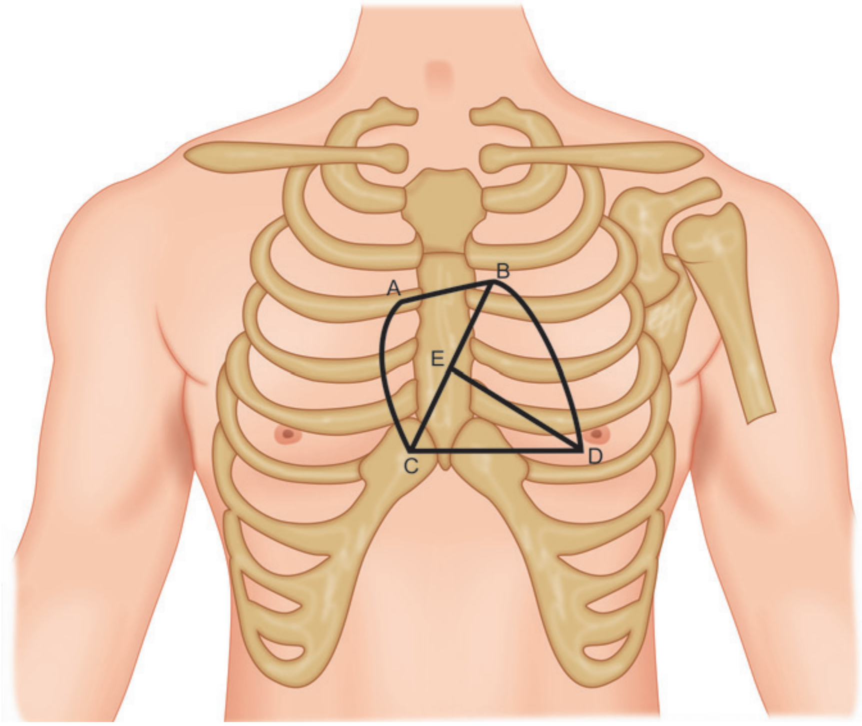

Fig. 2.3B: Coronary sulcus (CB) and anterior interventricular groove (ED).

Apex Beat (Fig. 2.4)

This is the farthest point of the heart. This is positioned at the left 5th intercostal space, just medial to the midclavicular line.

This is approximately 9 cms from the midsternal line.

Applied Anatomy

This is the most commonly accessed part of the heart during clinical examination. The heart beat is felt in this position. The apex beat which can be palpated and auscultated by using a stethoscope is due to the vortex like motion of the left ventricle.

Applied Anatomy

The region of the chest wall bounded by the borders of the heart is called the precordial area. The borders of the heart can be identified by percussion (though not in use now a days).

***Method of assessing the heart borders*:**

1. The apical impulse is first localized by inspection and then palpation. Any shift indicates cardiomegaly (enlargement of the heart)—mainly involving the left ventricle as

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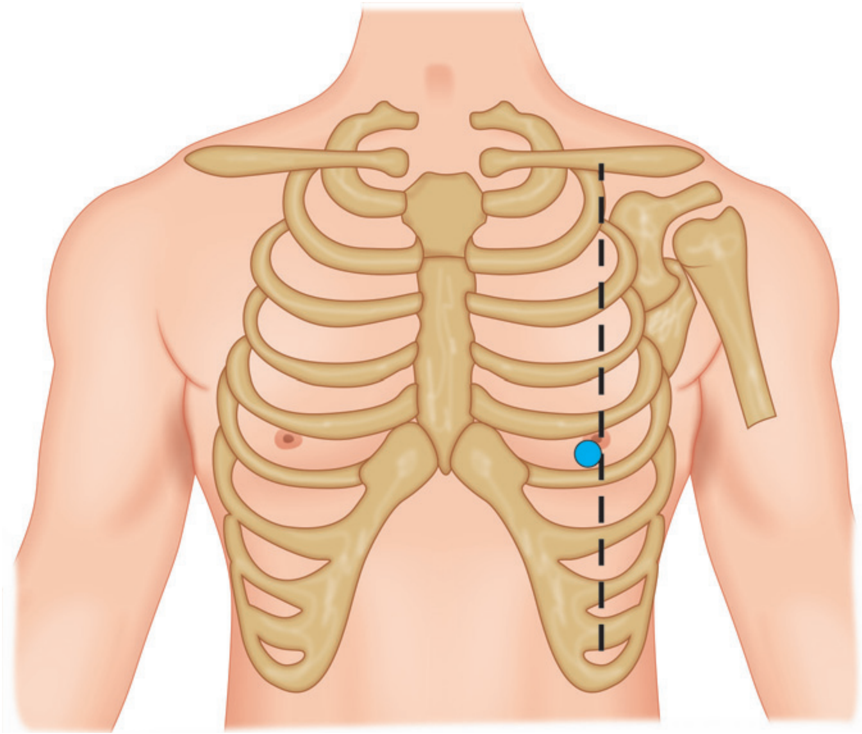

Fig. 2.4: Apex of the heart.

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can be seen secondary to severe mitral regurgitation, severe coronary artery disease. The apical impulse and thus the heart my be pushed laterally some times because of lung pathologies like large pleural effusion on the right side, pneumothorax on the right etc. In pericardial effusion though the apex is shifted outward by percussion, the apical impulse is not visible or palpable and may sound muffled or absent on auscultation due to presence of fluid in the pericardium.

2. The left 2nd parasternal (intercostal) space is percussed for dullness as well as pulsations. Presence of both is indicative of pulmonary arterial hypertension or dilatation.
3. The right heart border is determined by percussing from lateral to medial from the midclavicular line in the 4th intercostal space to determine the lateral most point of dullness which corresponds to the right atrium. It is normally within 4 cm from the midline and any value beyond this indicates a dilated right atrium (as in severe mitral valvular stenosis, Tricuspid regurgitation etc.).
4. The 2nd intercostal space on the right is also similarly percussed from laterally upto the sternal margin. Any dullness lateral to the parasternal area in this space could be due to lymphnodes, thymus, etc.

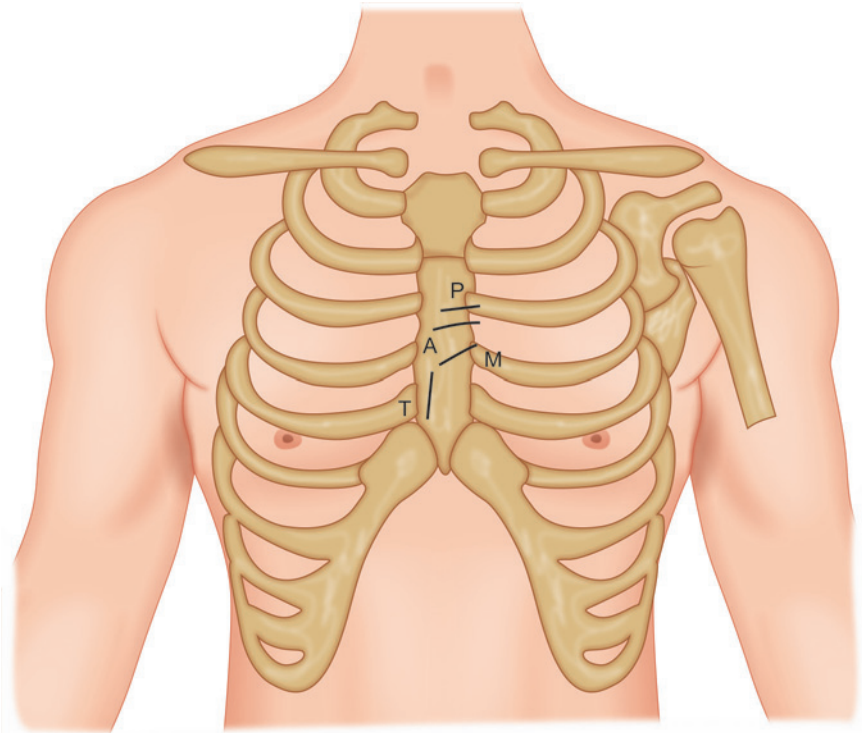

Fig. 2.5: Orifices of the heart.

Orifices of the Heart (Fig. 2.5)

These are mainly the valvular openings of the heart. They are the tricuspid, mitral, pulmonic and the aortic valvular areas.

A. The ***tricuspid valve*** is situated behind the sternum in a vertical plane extending from the 4th to the 5th intercostal space. It is 4 cms long and vertically placed (T).

B. The ***Mitral valve*** is situated behind the left margin of the sternum at the level of the fourth costal cartilage (M).

C. The ***pulmonary valve*** orifice is situated at the level of the left 3rd costal cartilage and partly behind the sternum. It is horizontally placed and is 2.5 cms long (P).

D. The ***aortic valve*** is very close to the ***pulmonary valve***. It is situated in the 3rd intercostal space behind the left half of the sternum with an inclination downwards and medially (A).

Thus the valves are more or less situated behind the sternum and closely placed. But the area of auscultation for these valves is a farther away from the valvular orifices. This is because the murmurs or the sound created by these valve closures are best heard in these areas as they are not covered by the sternum and they are in the direction of blood flow from the valvular orifices.

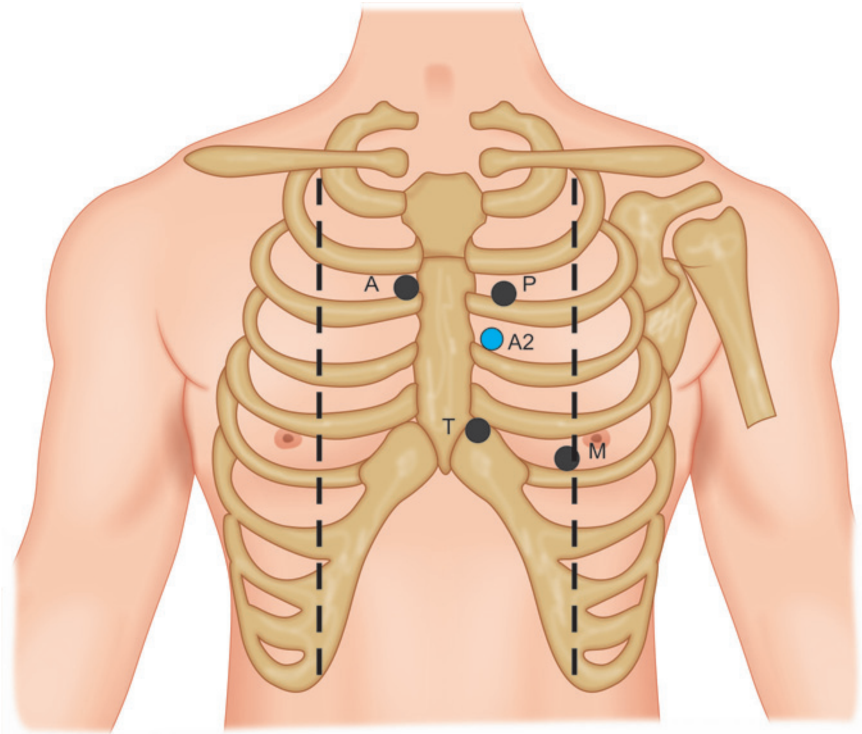

Fig. 2.6: Auscultatory areas of the heart.

Auscultatory Areas of the Heart (Fig. 2.6)

There are mainly four valves of the heart. They are the mitral, tricuspid, aortic and the pulmonary valve.

1. The tricuspid valve can be heard at the left lower part of the sternum in the 5th intercostal space (T).
2. The mitral valve can be heard in the left 5th intercostal space near the apex beat (M).
3. The pulmonary valve is in the left 2nd intercostal space near the lateral end of the sternum (P).
4. The aortic valve is in the right 2nd intercostal space near lateral end of the sternum (A).
5. The left 3rd intercostal space near the lateral border of the sternum is also called the **neo aortic or 2nd aortic (A2) area** as, some aortic valvular pathologies such as the murmur of aortic valve incompetence is better heard here.

Applied Anatomy

Learning to identify the auscultatory areas is important as we regularly auscultate these areas to confirm the normal heart sounds and be able to diagnose the different murmurs created due to the valvular abnormalities such as mitral valve regurgitation, aortic stenosis

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etc. The auscultatory areas might differ in their position in rare cases as *dextrocardia* and lung diseases which push the heart toward the opposite side.

The best position to auscultate the heart is in the *sitting position*. This is because the heart is closer to the anterior thoracic wall and the sounds will be heard clearly than in supine position as the heart falls away from the thoracic wall.

***Pericardiocentesis*:** This is a procedure to aspirate the excess pericardial fluid in cases of pericardial effusion and cardiac tamponade. Here the pericardial cavity is accessed in three ways.

1. ***Subxiphoid approach*:** This is the most commonly used approach. The angle between the xiphoid process and the left costal margin is identified. With a sagittal angulation of 30–45°, the canula is pushed forward pointing toward the left shoulder to reach the pericardial cavity.
2. The ***parasternal approach*** is an alternative method of performing emergency pericardiocentesis. The needle is inserted perpendicular to the chest wall in the 5th intercostal space, just lateral to the sternum
3. An ***apical approach*** using a shorter needle in which the needle is inserted in the intercostal space below and 1 cm lateral to the apical beat, aimed toward the right shoulder. This is done if adequate fluid is visible in this region by echocardiography. This approach is usually used only in case of large effusion or tamponade.

The depth of access in both approaches is guided by ultrasonography of the precordium.

Applied Anatomy

***Referred pain*:**

In myocardial infarction the patient usually complains of heaviness in the precordial area. This pain also radiates to the inner aspect of the left upper arm. This is because of the distribution of the T2 thoracic nerve which supplies the anterior thoracic wall partially and also the inner aspect of the upper arm as intercostobrachial nerve. Apart from this, the pain may also be felt in some other areas such as the left side of the face and neck, the whole of the left upper limb. This is called referred pain.

Surface Anatomy of the Lungs

***Pleura*:** The pleura is a serous covering of the lungs. This helps in the frictionless movements of the lungs during respiration. It can be divided into as cervical, costal and mediastinal pleura. Only the costal and the cervical pleura can be drawn on the anterior thoracic surface.

Cervical Pleura (Fig. 2.7A)

Cervical pleura are drawn as an inverted V shape about 1 inch above the medial third of the clavicle in the neck (A).

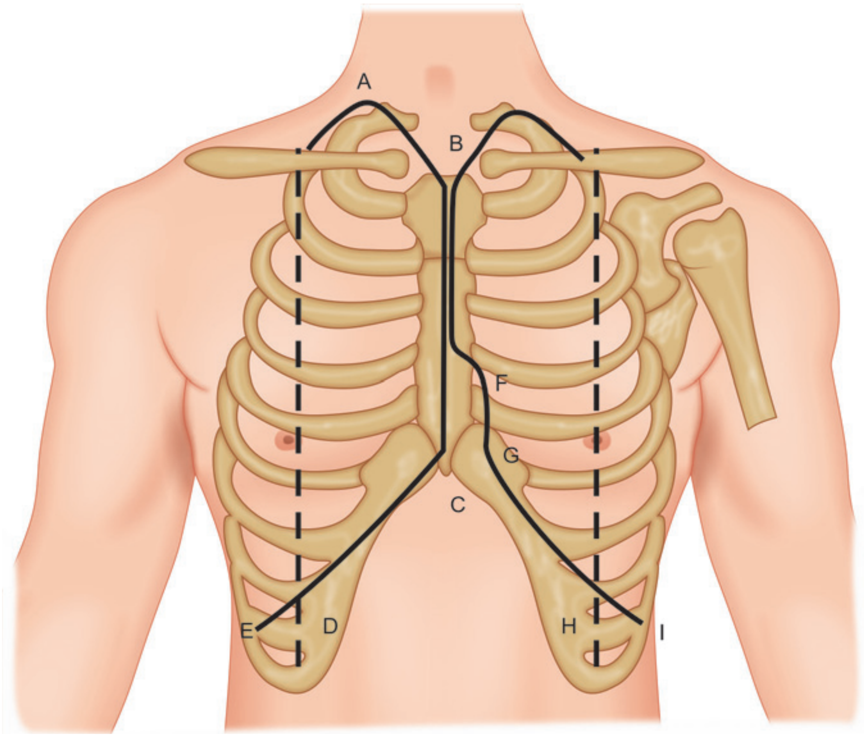


Fig. 2.7A: Pleural reflections on the front of thorax.

Costal Pleura

***Right side*:** The **anterior margin** extends as a vertical line over the midsternal line from the suprasternal margin up to the xiphisternal joint (BC).

The **inferior margin** is drawn from the xiphisternal joint to cross the 8th rib in the midclavicular line, 10th rib in the midaxillary line (CDE) and the 12th rib in the paravertebral line (2 cms lateral to the spinous process of the 12th thoracic vertebra) [Fig. 2.7B (IJ)].

The **posterior margin** is drawn as a vertical line from the spinous process of the seventh cervical vertebra to the 12th thoracic vertebra. The line is 2 cms lateral to the spinous processes of the vertebrae.

***Left side*:** The **anterior margin** extends as a vertical line over the midsternal line from the suprasternal margin up to the 4th costal cartilage (BF). Then it deviates to the left along the left lateral sternal border up to the 6th costal cartilage (FG).

The **inferior margin** is drawn from the 6th costal cartilage to meet the 8th rib in the midclavicular line, 10th rib in the midaxillary line (GHI) and the 12th rib in the paravertebral line (IJ).

The **posterior margin** is drawn as a vertical line from the spinous process of the 7th cervical vertebra to the 12th thoracic vertebra. The line is 2 cms lateral to the spinous processes of the vertebrae [Fig. 2.7B (KJ)].

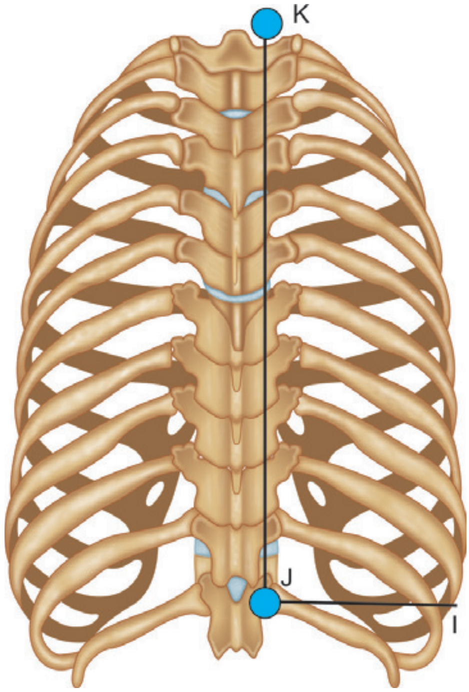


Fig. 2.7B: Pleural reflections on the back of thorax.

Applied Anatomy

Pleurocentesis is an invasive procedure done in order to draw pleural fluid in cases of pleural effusion for evaluation of the effusion also as treatment if the effusion is large. This is usually done in the intercostal space along the superior surface of the lower rib. The level of intercostal space is determined by the level of the fluid by X-ray. The level of the effusion should be confirmed on the basis of diminished or absent sounds on auscultation, dullness to percussion, and decreased or absent fremitus. The needle should be inserted one or two intercostal spaces below the level of the effusion, 5–10 cm lateral to the spine (In the space between the scapular line and midline posteriorly). To avoid intraabdominal injury, the needle should not be inserted below the 9th rib.

Lungs (Fig. 2.8A)

***Apex of the lungs*:** is drawn in the neck about 2.5 cms above the medial 3rd of the clavicle along the pleural reflection (A).

Right lung*:** The ***anterior margin extends as a vertical line over the midsternal line from the suprasternal margin upto the xiphisternal joint (BC).

The ***inferior margin*** is drawn from the xiphisternal joint to cross the 6th rib in the midclavicular line, 8th rib in the midaxillary line (CDE) and the 10th rib in the paravertebral line [Figs. 2.8A and B, (IJ)].

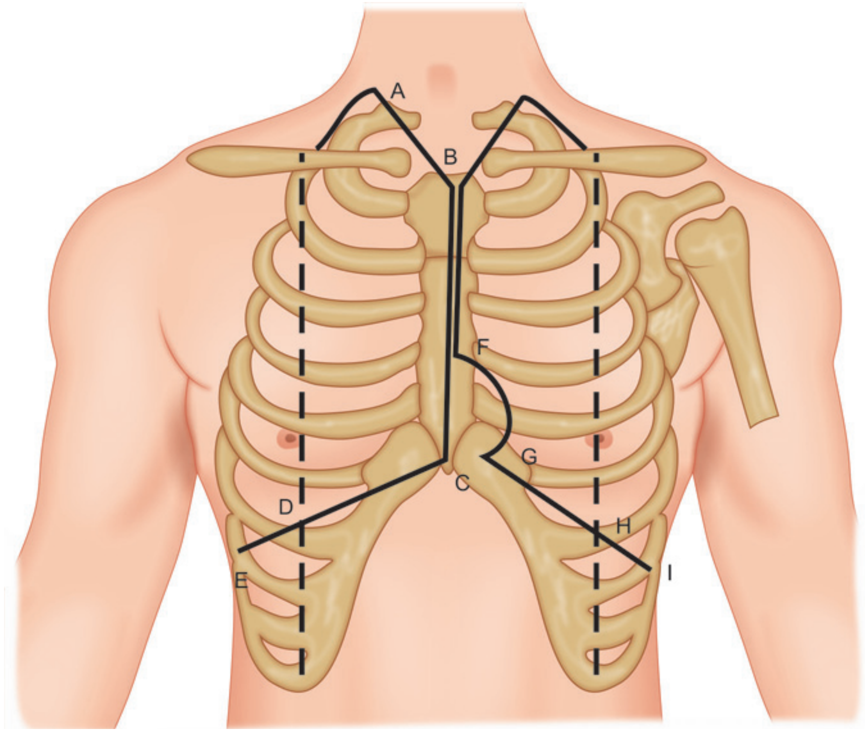


Fig. 2.8A: Borders of lung on the front of thorax.

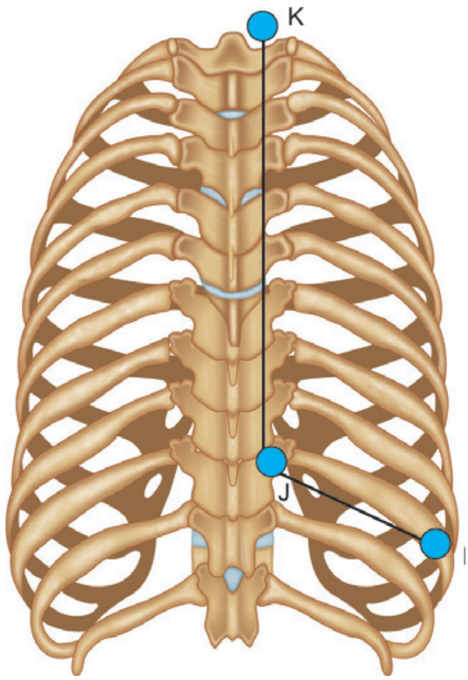


Fig. 2.8B: Borders of the lung on the back of thorax.

The ***posterior margin*** is drawn as a vertical line from the spinous process of the 7th cervical vertebra to the 10th thoracic vertebra. The line is 2 cms lateral to the spinous processes of the vertebrae (Fig. 2.8B, KJ).

Left lung*: The *anterior margin extends as a vertical line over the midsternal line from the suprasternal margin upto the 4th costal cartilage (BF). Then it deviates to the left along the left lateral sternal border. From here the line curves 3.5 cms lateral to the lateral sternal border and then reach the 6th costal cartilage (FG).

The ***inferior margin*** is drawn from the xiphisternal joint to cross the 6th rib in the midclavicular line, 8th rib in the midaxillary line (GHI) and the 10th rib in the paravertebral line (Fig. 2.8B, IJ).

The ***posterior margin*** is drawn as a vertical line from the spinous process of the 7th cervical vertebra to the 10th thoracic vertebra. The line is 2 cms lateral to the spinous processes of the vertebrae (Fig. 2.8B, KJ).

***Fissures of the lung (Figs. 2.9A and B)*:** These fissures cut through the lung till the hilum into three lobes on the right lung and two lobes on the left lung.

***Oblique Fissure*:** This can be drawn as an oblique line starting from the 2nd thoracic vertebra posteriorly to meet the 6th rib in the midclavicular line anteriorly. This fissure is present in both the lungs.

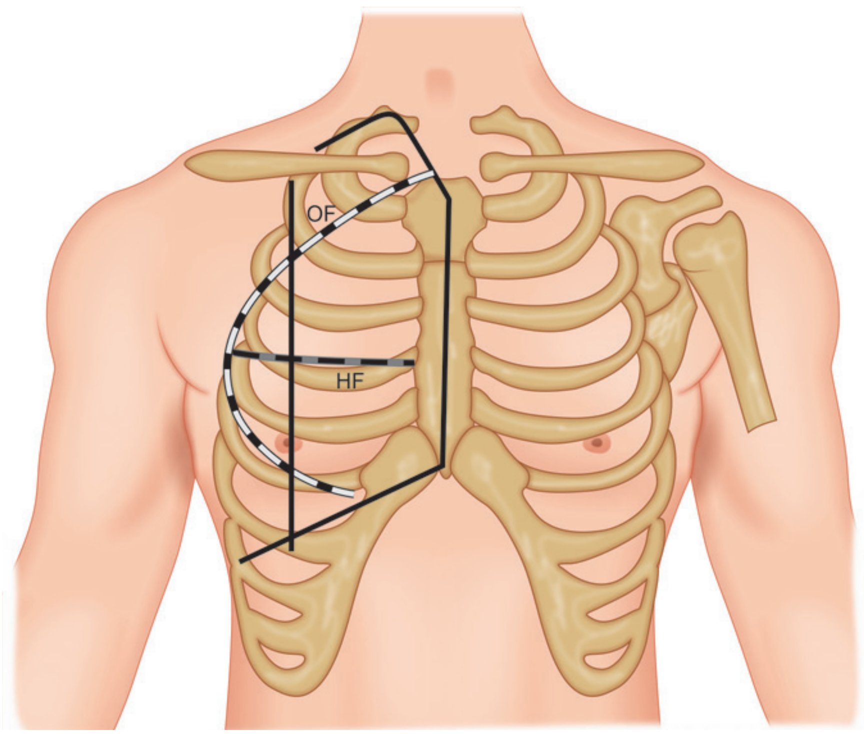


Fig. 2.9A: Fissures of lung. (OF: Oblique fissure; HF: Horizontal fissure).

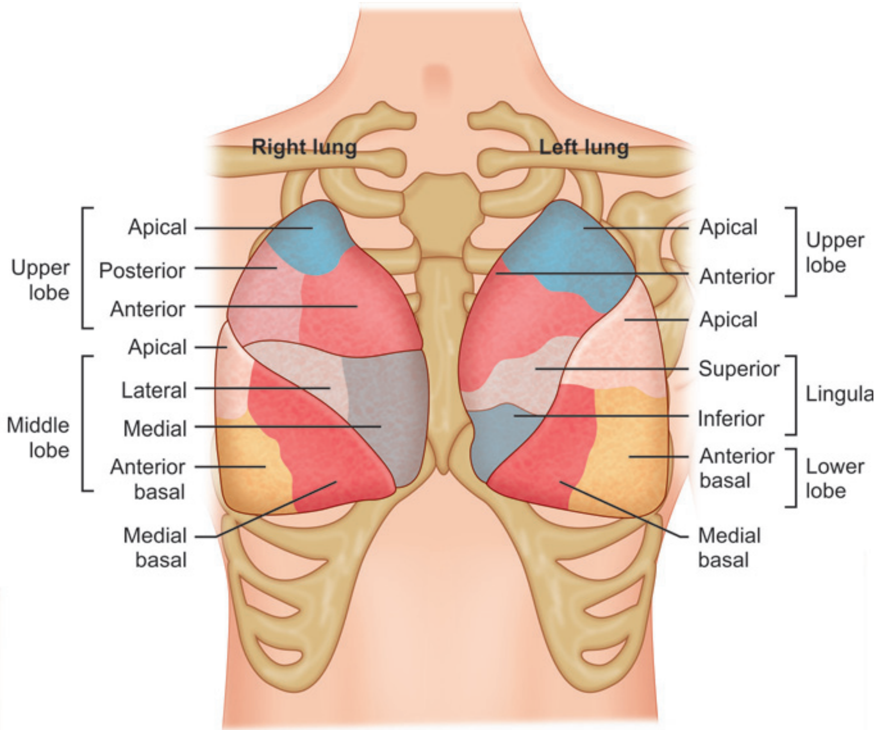


Fig. 2.9B: Bronchopulmonary segments.

***Horizontal fissure*:** Drawn as a horizontal line from the point where the oblique fissure meets the midaxillary line to the midsternal line along the 4th costal cartilage. This is present in the right lung.

Hence the right lung is divided into three lobes by the oblique and the horizontal fissures. The left lung is divided into two lobes by the oblique fissure only.

Applied Anatomy

Orientation of the lobes of the lung to the thoracic surface:

The oblique fissure because of its obliquity projects the upper lobe to the anterior thoracic wall and the lower lobe to the posterior thoracic wall as shown in the diagram. Hence when the anterior thoracic wall is palpated and auscultated for respiratory sounds, the student should have the upper lobe in mind and similarly the lower lobe when examining the posterior thoracic wall.

Ascending Aorta (Fig. 2.10)

The aorta is the outlet of the left ventricle. It is marked by

a. A point on the left of the mid sternal line at the 3rd costal cartilage (A).

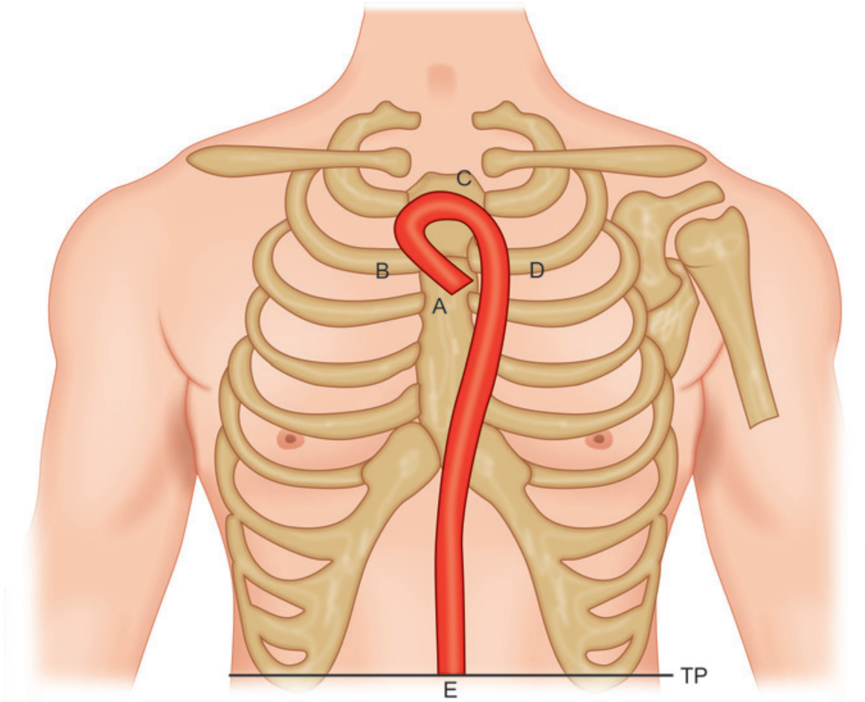


Fig. 2.10: Ascending arch and descending thoracic aorta. (AB: Ascending aorta; BCD: Arch of aorta; DE: Descending thoracic aorta; TP: Transpyloric plane).

b. A point to the 2nd costal cartilage on the right side at the border of the sternum (B).
c. The direction of the ascending aorta is from the left to the right and upwards.

Applied Anatomy

The ascending aorta and arch of the aorta are some of the common sites of aneurysmal dilatation (disproportionate/abrupt dilatation of a part/segment of a blood vessel). This can cause compression of the adjacent veins, nerves, trachea/bronchi, esophgus and patient will present with corresponding symptoms. Clinically this can be suspected when we find superior mediastinal widening on percussion, i.e. dullness extending more than half an inch lateral to the sternal border on either side in the 2nd and 3rd intercostal spaces. (Differential diagnoses) Thymoma, ectopic thyroid, pulmonary arterial dilatation on the left side, lymph nodes.

Arch of the Aorta (Fig. 2.10)

The arch of the aorta is the continuation of the ascending aorta. It is marked by:
a. A point on the right 2nd costal cartilage at the lateral border of the sternum (B).
b. A point on the midsternal line 2.5 cms below the jugular notch (C).
c. A point of the left 2nd costal cartilage on the lateral border of the sternum (D).
d. Join B, C and D by a double line of 2 cms width.

Descending Thoracic Aorta (Fig. 2.10)

The descending aorta is the continuation of the arch of the aorta. It is marked by:

a. A point on the left 2nd costal cartilage at the lateral border of the sternum (D).
b. A point in the midline, 2 cm above the transpyloric plane (E).
c. Join D and E by double lines 2 cm apart.

Inominate Artery, Left Common Carotid and Left Subclavian Artery

The ***innominate artery*** (brachiocephalic artery) arises in the midline from the arch of the aorta (A) and extends to the right sternoclavicular joint (B) (Fig. 2.11).

To the left of this is the origin of the **left common carotid artery** (C) which extends to the left sternoclavicular joint (Fig. 2.11).

Then mark a point to the left of left common carotid artery (C). Mark the left sternoclavicular joint. Join the points (D). This marks the **left subclavian artery** (Fig. 2.11).

Internal Thoracic Artery (Fig. 2.12)

This is the only branch of the subclavian artery which descends downwards. It is marked by:

a. A point 2 cms above the sterna end of the clavicle (A).
b. A line from the above point, 1 cm lateral to the lateral sternal margin (B).
c. A point at the sternal end of the 6th costal cartilage (C).

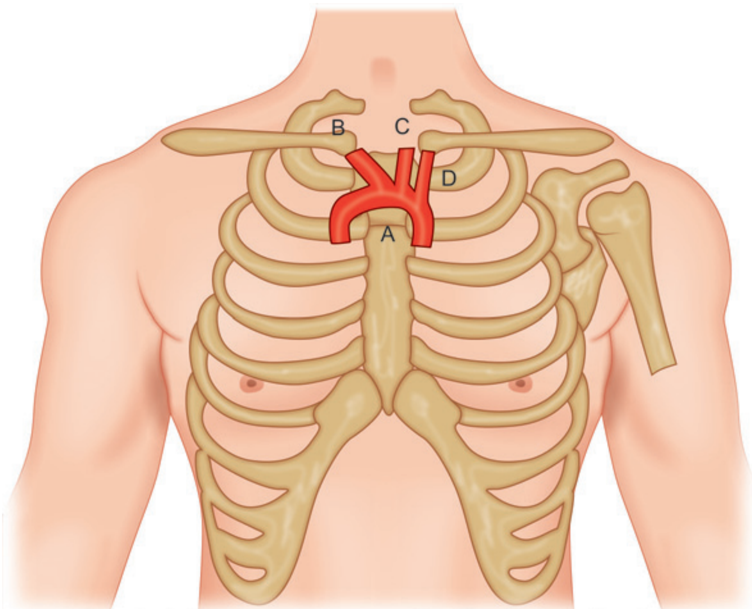


Fig. 2.11: Brachiocephalic, left common carotid, and left subclavian artery. (A: Arch of aorta; B: Brachiocephalic artery; C: Left common carotid artery; D: Left subclavian artery).

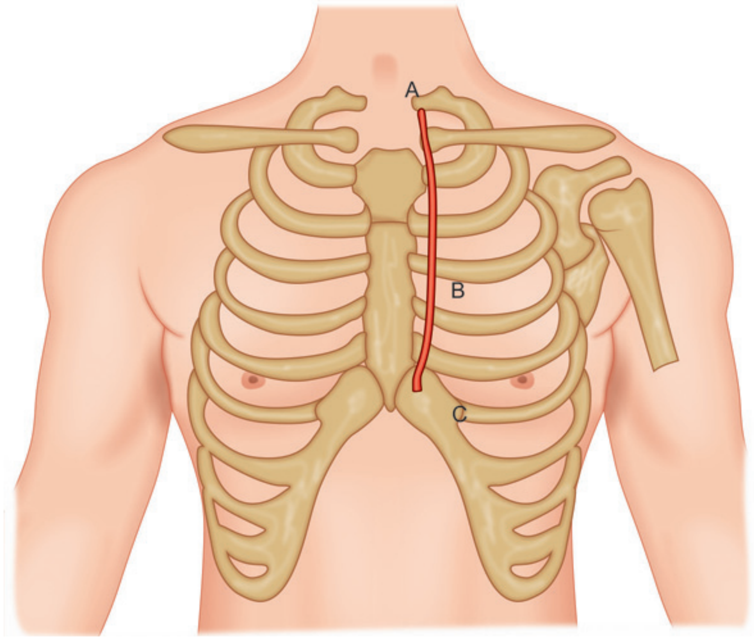


Fig. 2.12: Internal thoracic artery.

Applied Anatomy

The internal thoracic artery needs ligation in cases of cardiac bypass and breast procedures. The best area to access is in the 2nd and 3rd intercostal spaces as these are the widest and the artery can be accessed at 1 cm lateral to the sternal margin.

Right Brachiocephalic Vein (Fig. 2.13)

a. A point on the right sternoclavicular joint.
b. A point on the right 1st costal cartilage, 1 cm lateral to the lateral sternal margin.

Left Brachiocephalic Vein (Fig. 2.13)

a. A point on the left sternoclavicular joint.
b. A point on the right 1st costal cartilage, 1 cm lateral to the lateral sternal margin.
c. The direction is from the left to the right and downwards.

Superior Vena Cava (Fig. 2.14)

a. A point on the right 1st costal cartilage, 1 cm lateral to the lateral sternal margin (A).
b. A point on the upper border of the 3rd costal cartilage, 1 cm parallel to the lateral sternal margin (B).
c. Join the points A and B by two parallel lines 2 cms apart.

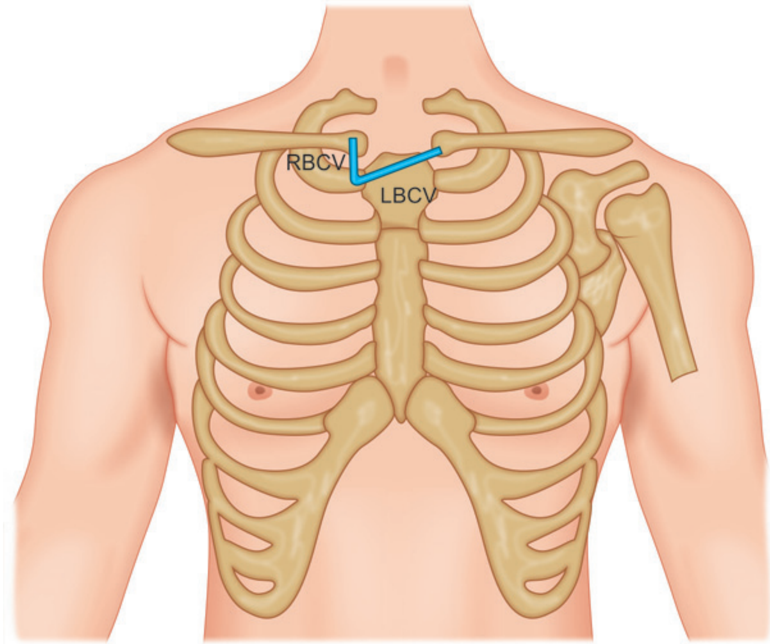


Fig. 2.13: Right and left brachiocephalic vein. (RBCV: Right brachiocephalic vein; LBCV: Left brachiocephalic vein).

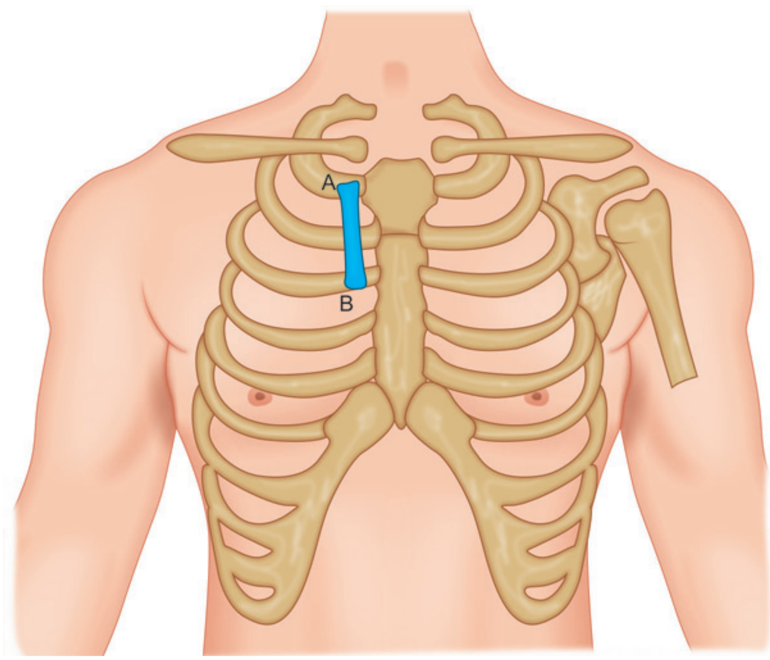


Fig. 2.14: Superior vena cava.

Esophagus (Fig. 2.15)

The surface marking is done on the back of the trunk.

a. A point on the 7th cervical spine. The spine of the 7th cervical vertebra is the most prominent spine on the back of the neck (A).
b. A point 2.5 cm lateral to the 9th thoracic vertebral spine. Both the points are marked on the left side (B).
c. Join both the points with two parallel lines around 2 cms apart.

Trachea (Fig. 2.16B)

The surface marking is done on the back of the trunk.

a. A point on the spinous process of the 6th cervical vertebra (A).
b. A point on the 4th thoracic spine (B).
c. This corresponds to the sternal angle on the front.
d. Join the above two points by two parallel lines 2 cms apart.

***Anteriorly*:** The trachea can be marked as follows: (Fig. 2.16A)

a. Mark a point below the cricoid cartilage (A).
b. Mark a point 1 cm to the right of the midpoint of the sternal angle (B).
c. Join these two points by two parallel lines 2 cms apart.

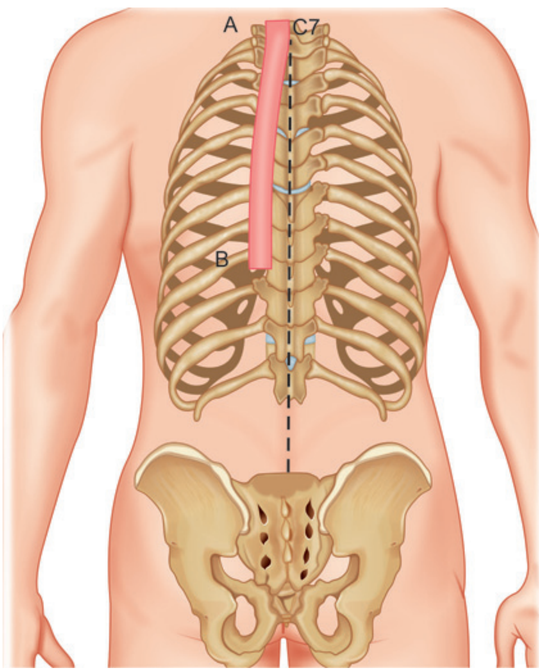
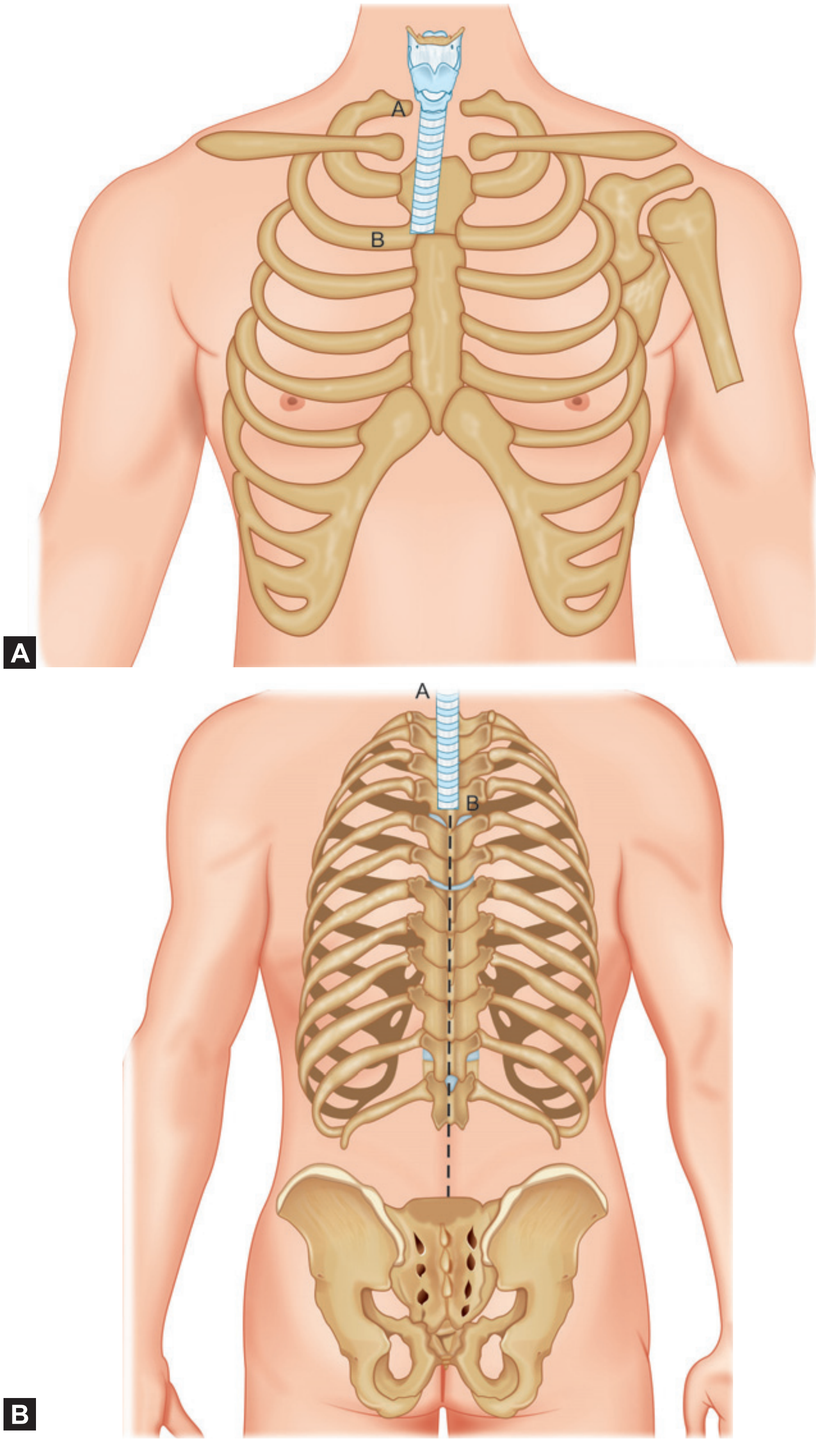


Fig. 2.15: Esophagus.



Figs. 2.16A and B: (A) Trachea from front. (B) Trachea from behind.

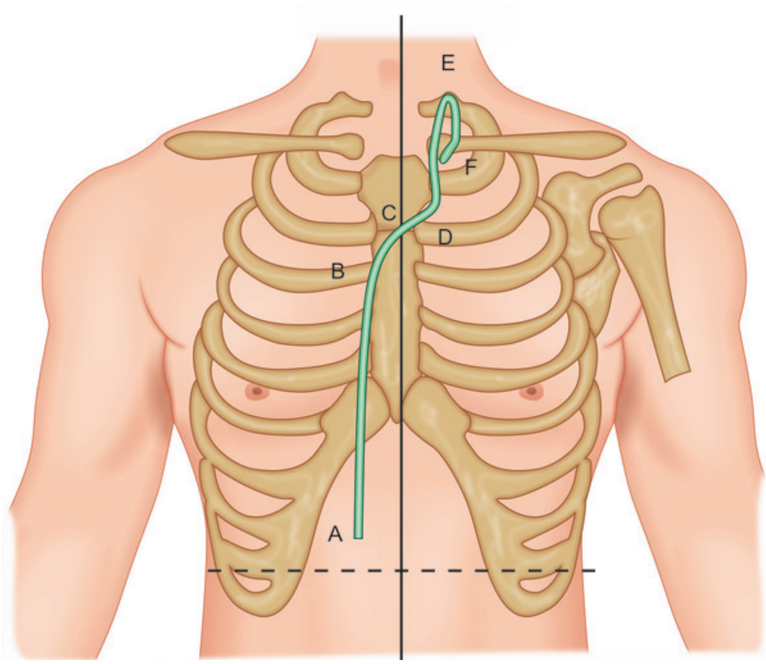


Fig. 2.17: Thoracic duct.

Thoracic Duct (Fig. 2.17)

a. Mark a point 2 cms above and 2 cms right lateral to the transpyloric plane from the midline (A).
b. Mark a point at the 3rd right lateral chondrosternal margin (B).
c. Mark a point at the midpoint of the sternal angle (C).
d. Mark a point to the 2nd left chondrosternal margin (D).
e. Mark a point 2 cms from the midline and 2.5 cms above the left clavicle (E).
f. Mark a point at the left sternoclavicular joint (F).
g. Join A through F.

Root of Lungs (Fig. 2.18)

These are marked in prone position.

a. Mark the spines of 4th, 5th and 6th thoracic vertebrae.
b. Mark a vertical oval area about 2.5 cms lateral to the spines mentioned above. (midway between the spines and medial border of the scapula.

Surface Anatomy of the Intercostal Spaces

The intercostals spaces are areas between the ribs. This is containing the intercostal muscles, vessels and nerves.

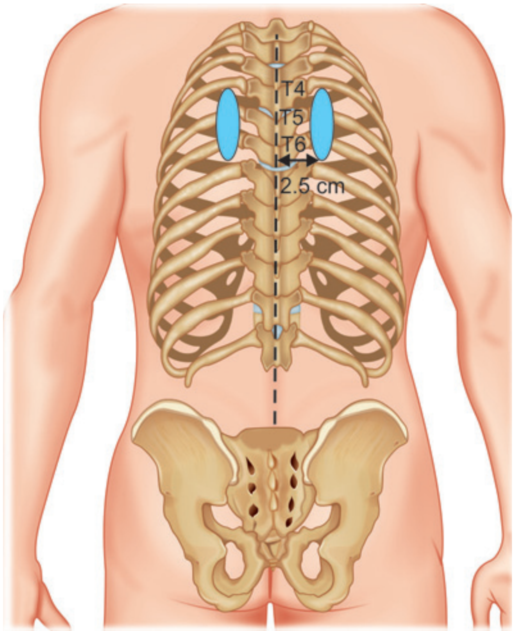


Fig. 2.18: Root of lungs.

They are of much importance to the physicians and surgeons because they are utilized for many of the invasive procedures as mentioned below.

The 2nd rib and intercostal space are important. The 2nd rib attaches to the sternum at the manubriosternal angle and forms a bony landmark for counting the intercostal spaces.

Applied Anatomy

The intercostal spaces should be approached in the middle of the intercostal space or toward the lower boundary of the space. This is because access toward the upper boundary of the intercostal space will lead to injury to the intercostal nerves and vessels in the costal grove.

The minimally invasive cardiac access surgery is done by a small incision of 3–4 cms in the 4th or the 5th intercostal space on the left side. This avoids the large median sternotomy and postoperative complications and long stay in the hospital.

Minimally invasive cardiac procedures:

- Procedure for Treatment of Atrial Fibrillation (MAZE)
- Minimally Invasive Direct Coronary Artery Bypass (MIDCAB)
- Multi-Vessel Small Thoracotomy
- Single-Vessel Small Thoracotomy
- Minimally Invasive Heart Valve Surgery
- Minimally Invasive Treatment for Septal Defects [atrial septal defect (ASD) and ventricular septal defect (VSD)].

Surface Anatomy of the Abdomen

3

The abdomen extends from the diaphragm to the pelvic diaphragm. The abdominal wall can be divided into nine quadrants by imaginary lines. The bony landmarks for the anterior abdominal wall are (Figs. 3.1A, B, and 3.2):

a. ***The costal margin*:** This is the lower margin of the ribcage formed by the union of the costal cartilages of the 7th to 10th ribs
b. ***The xiphisternum*:** This is the point where the lower end of the sternum meets the xiphoid process
c. Upper 6 costal cartilages
d. Tubercle of the iliac crest: This might not be visible. It can be marked 5 cms behind the anterior superior iliac spine on the outer lip of the iliac crest.
e. Anterior superior iliac spine

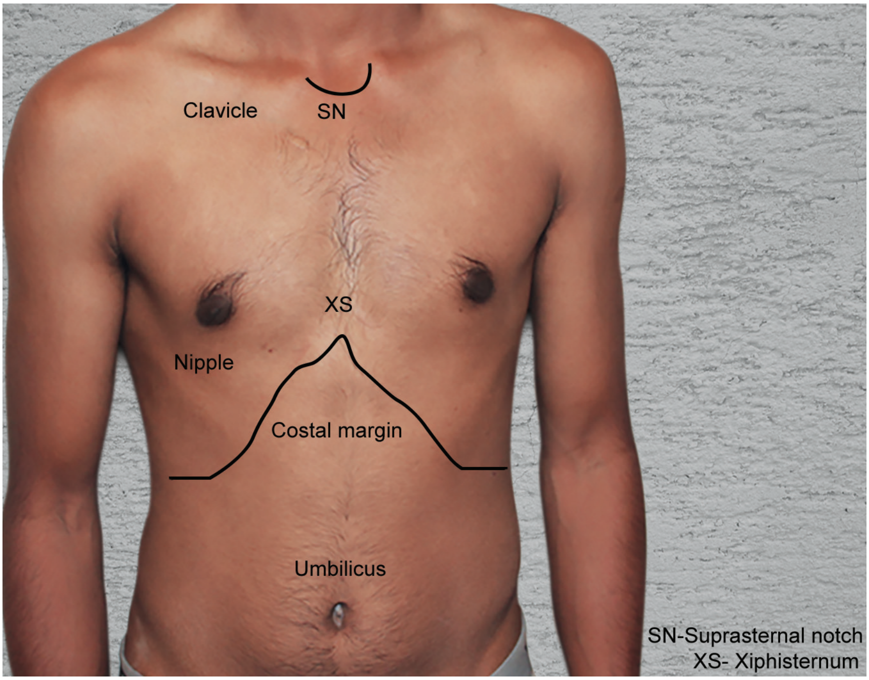


Fig. 3.1A: Bony and soft tissue landmarks.

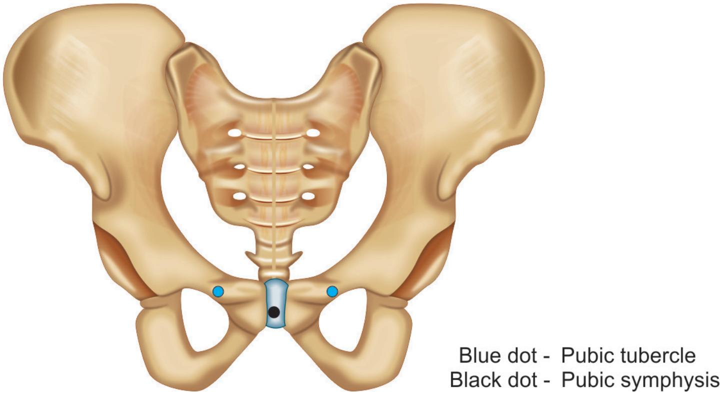


Fig. 3.1B: Landmarks of the pelvis.

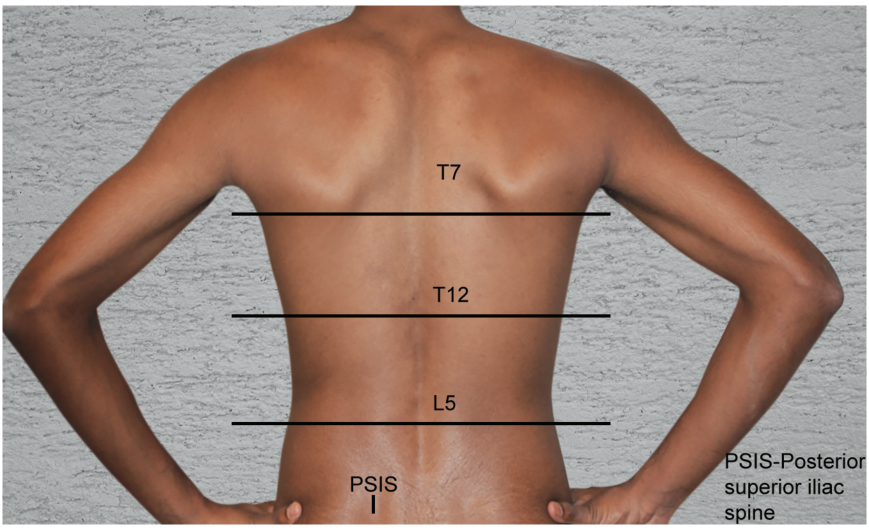


Fig. 3.2: Landmark on the back.

f. Pubic symphysis is the joint between the medial ends of the pubic bone
g. Pubic crest extends from the pubic tubercle to the medial end of the pubic bone
h. Pubic tubercle is a projection on the upper border of superior ramus of pubis about 1.5 cms from the pubic symphysis at the lateral end of the pubic crest.

The ***soft tissue landmarks*** are:

a. ***Umbilicus***—this forms an important soft tissue landmark. It forms the watershed line for the arterial supply, venous drainage and lymphatic drainage.

On the back of the abdomen the bony landmarks are (Fig. 3.2):

a. Lower thoracic spines

b. Lumbar spines
c. Posterior superior iliac spine
d. Posterior inferior iliac spine
e. Coccyx.

REGIONS OF THE ANTERIOR ABDOMINAL WALL (Fig. 3.3)

The anterior abdominal wall can be divided into nine segments by the following lines. Mark the following points and draw the lines.

a. A point is marked at the tip of the ninth costal cartilage in the midclavicular line on both sides. Draw a horizontal line touching the two points. This represents the transpyloric plane.
b. A point is marked on the tubercle of the iliac crest of both the sides and a transverse line is drawn crossing the points. This represents the transtubercular plane.
c. A vertical line is drawn through the midclavicular lines on both sides.
d. This divides the abdominal wall into nine quadrants.
e. The upper and lateral quadrants are called hypochondriac as they lie beneath the costal margin.
f. The upper middle quadrant is called the epigastric region. The middle lateral quadrants are called lumbar quadrants. The central quadrant is called the umbilical quadrant.
g. The lower lateral quadrants are called as the iliac quadrants. The lower middle quadrant is called as the hypogastric quadrant.

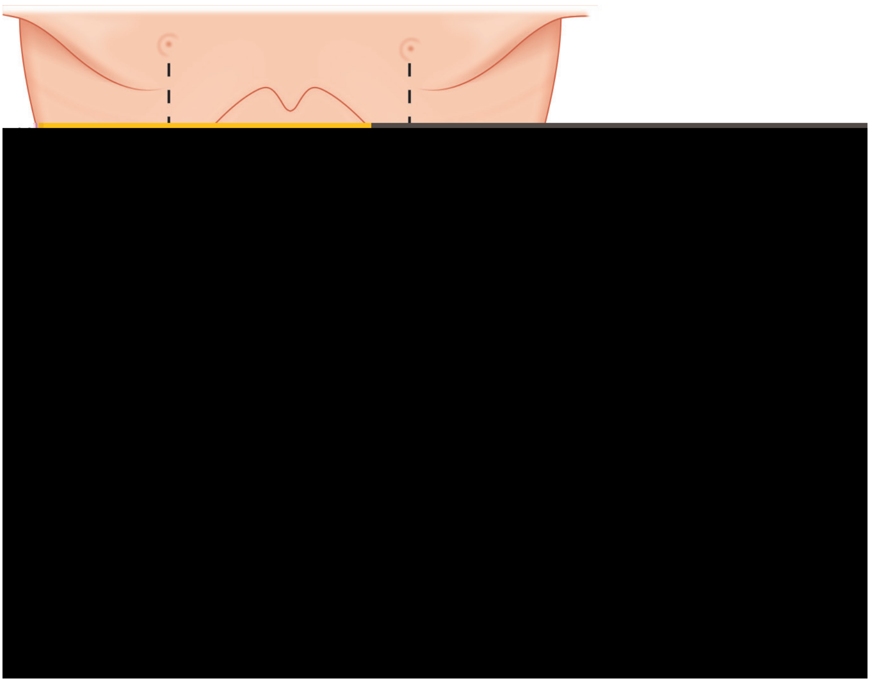


Fig. 3.3: Planes and quadrants of the anterior abdominal wall.

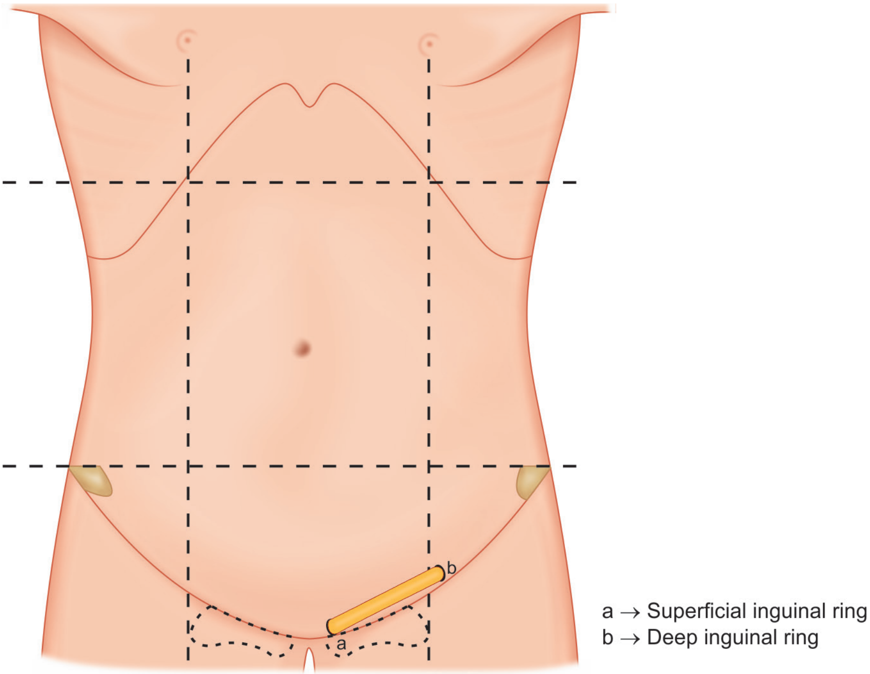


Fig. 3.4: Inguinal canal.

Inguinal Canal (Fig. 3.4)

a. Mark the *deep inguinal ring* by a point 1.25 cms above the midpoint of the inguinal ligament.
b. Mark the *superficial inguinal ring* by a point 1 cm above and lateral to the pubic tubercle.
c. Join these two point by two parallel lines 1 cm apart. This marks the inguinal canal.

Applied Anatomy

The deep inguinal ring (DIR) and superficial inguinal ring (SIR) is identified and closed alternatively by thumb pressure to differentiate and diagnose direct and indirect inguinal hernia respectively. On closure of the SIR, if the hernia increase on coughing then the hernia is a direct one. On closure of the DIR, if the hernia does not increase on coughing it indicate an indirect inguinal hernia.

The pubic tubercle is the most important landmark for clinical examination of the inguinal hernia. The inguinal hernial sac lies above and medial to the pubic tubercle where as the femoral hernia sac lies below and lateral to the pubic tubercle.

Stomach (Fig. 3.5)

The stomach lies in the left hypochondriac, epigastric and extends into the umbilical region in obese persons. It is marked by the following points:

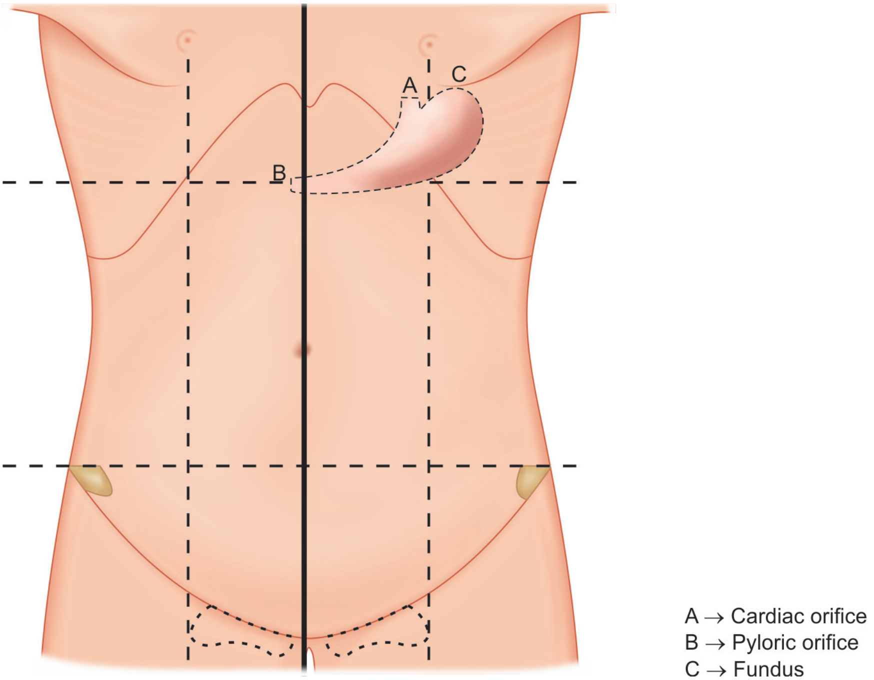


Fig. 3.5: Stomach.

a. The cardiac orifice is marked on the left 7th costal cartilage, 2.5 cms to the left of the left sternal margin (A).
b. The pyloric orifice is marked on the transpyloric plane 1 cm to the right of the midline (B).
c. The lesser curvature is drawn as a vertical curved line from the cardiac to the pyloric orifice with convex downwards as shown in the Figure 3.5.
d. The fundus is drawn as an upper convexity reaching upto the left 5th intercostal space on the left (C).
e. The greater curvature is drawn as a continuation of the fundus to the pyloric orifice. The greater curvature should cross the junction of the left lateral line and the transpyloric plane.

Applied Anatomy

***Traube's Space*:** This is a crescent space bounded by the (Fig. 3.6)
a. Lower margin of the left lung, anterior border of the spleen (B).
b. Left costal margin (C).
c. Inferior margin of the liver along the left sixth rib (A).

This can be marked by drawing a line along the lower border of the left 6th rib, a left anterior axillary line laterally and along the left costal margin.

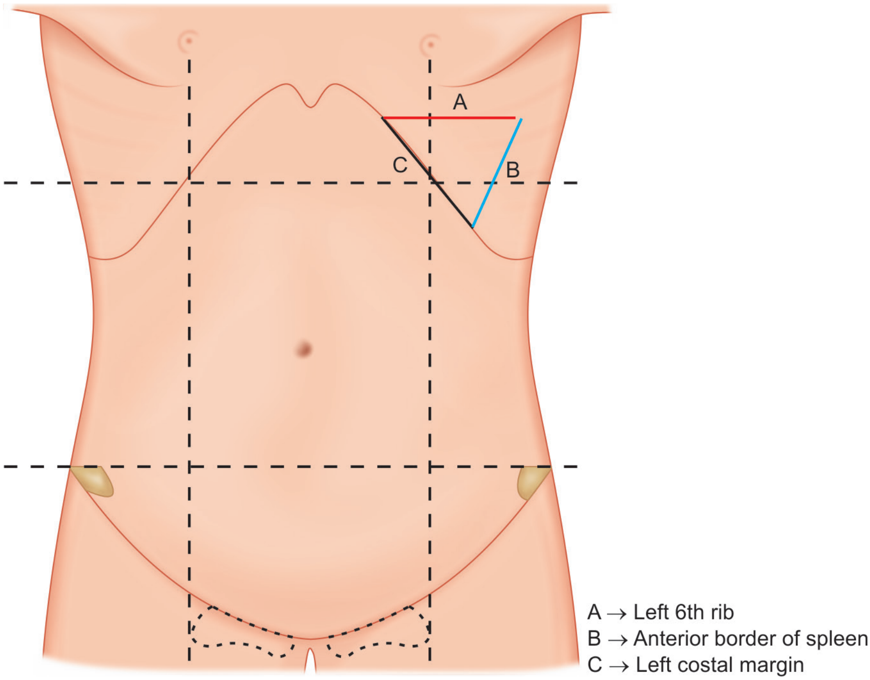


Fig. 3.6: Traube's area.

Applied Anatomy

On percussion on the Traube's space normally a tympanic sound is heard. In case of left pleural effusion or splenomegaly, the Traube's space becomes dull on percussion. In obese individuals, the normal tympanic sound might not be heard.

***Gastric triangle (Fig. 3.7)*:** This is the part of the abdominal wall where the anterosuperior surface of the stomach comes in direct contact with the anterior abdominal wall. It extends along the left costal margin laterally, the lower margin of the liver medially and transverse colon below.

Applied Anatomy

This triangle is used for insertion of the gastrostomy tube which is used to bypass the upper GI tract from the oral cavity to the fundus of the stomach in patients with obstruction or dysfunction of this segment of the GIT due to neurological diseases causing paralysis.

Duodenum (Fig. 3.8)

It is divided into four parts. The 1st part or ascending part, 2nd part or descending part, 3rd part or the horizontal part and the 4th part.

- The ***1st part*** is 2.5 cms and begins from the marking of pyloric orifice and ascends upwards to the right side (A).

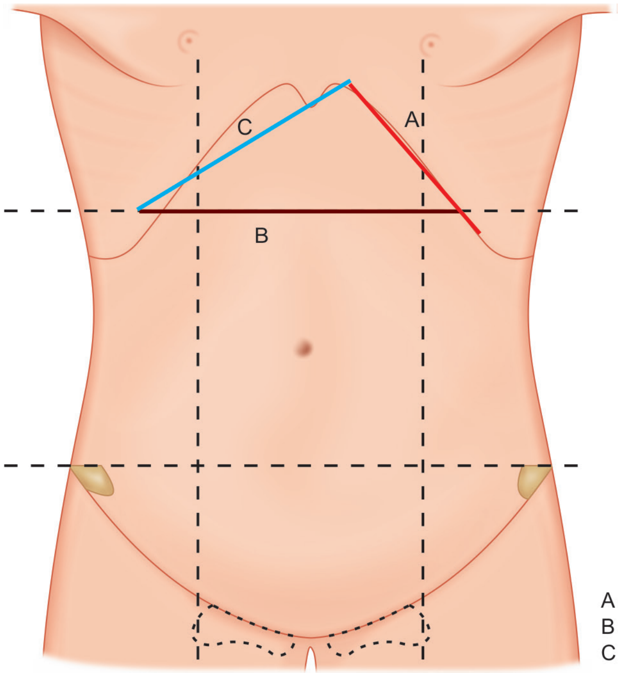


Fig. 3.7: Gastric triangle.

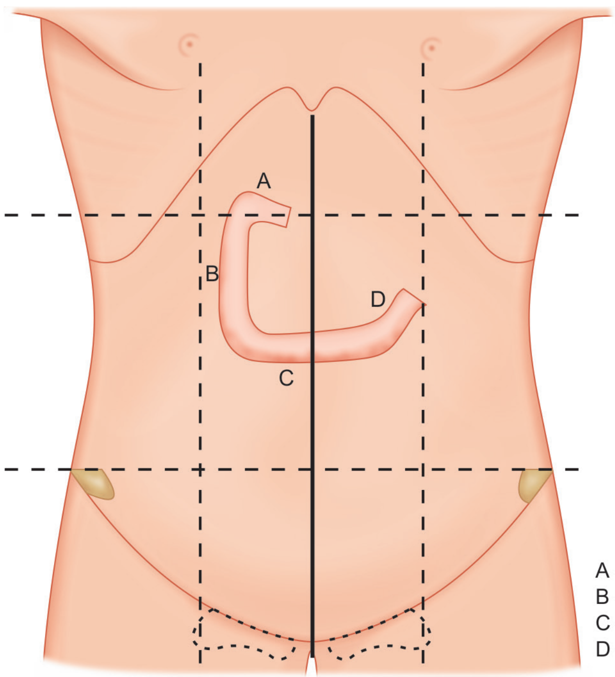


Fig. 3.8: Duodenum.

- *The **descending part*** descends down for 5 cms medial to the right lateral line to a point midway between the transpyloric and transtubercular plane (B).
- The ***horizontal part*** is continued horizontally and upwards to the left of the midline for 10 cms (C).
- The ***ascending part*** continues upwards toward the transpyloric line where it ends as the duodenojejunal flexure. This is marked about 2.5 cms to the left of the midline (D).

Applied Anatomy

Pathology involving the 2nd part of the duodenum or associated structures, such as the common bile duct, ampulla of Vater, head of the pancreas:

Duodenal ulcer pain/tenderness is felt about 2 inches lateral to the umbilicus on the right side.

Obstructive jaundice with mass on the right side of the abdomen in the umbilical region can be because of a malignancy of the head of the pancreas, CBD, or ampulla of Vater.

***Small intestine*:** The small intestinal loops are highly mobile and difficult to mark in a fixed position. This is because of the presence of mesentery. The coils of jejunum are predominantly present in the left lumbar and iliac regions. The ileal coils are present in the right umbilical and iliac regions. Some part of the ileum descends downward into the pelvis (Fig. 3.9).

Therefore **root of the mesentery** is marked to indicate the mobile part of the small intestine. It extends from a point 2.5 cm below and to the left of the junction between transpyloric

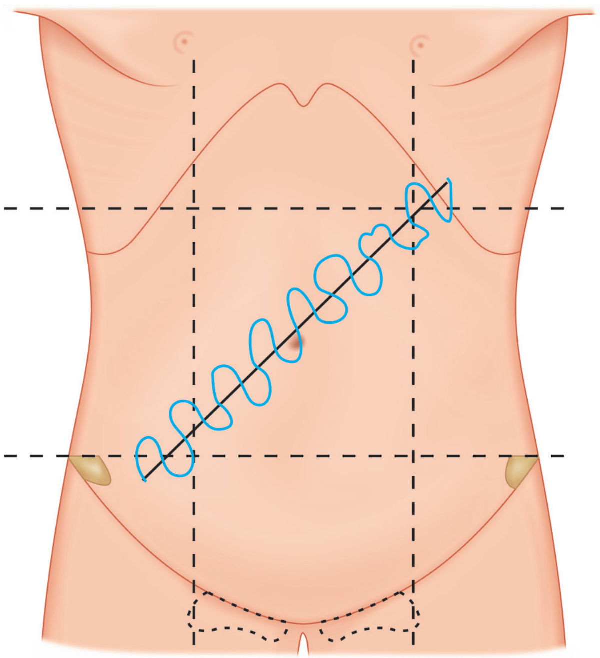


Fig. 3.9: Small intestine and root of mesentry.

plane and mid line. Another point on the right side anterior superior iliac spine which corresponds to upper border of sacroiliac joint (Fig. 3.9).

Join both points by an obliquely running line.

Applied Anatomy

Mass in the right iliac fossa is commonly due to
a. Appendicular mass—inflammatory or malignant
b. Ileocaecal tuberculosis
c. Malignancy involving the ileocaecal area
d. commomly intestinal lymphoid tumors.

Ileocolic Orifice (Fig. 3.10)

a. Mark a point at the junction of transtubercular and right lateral planes (A).

Applied Anatomy

The abdominal pain is vague, continuous dull aching and colicky. Gastrointestinal disturbances can cause pain in the abdomen. The pain usually is periumbilical and later radiates in different direction. This is because of embryological origin, wherein the small intestine is herniated out through the umbilical opening initially and then reenters to occupy the designated places of jejunal coils in the left upper quadrant and the ileal coils in the right lower quadrant.

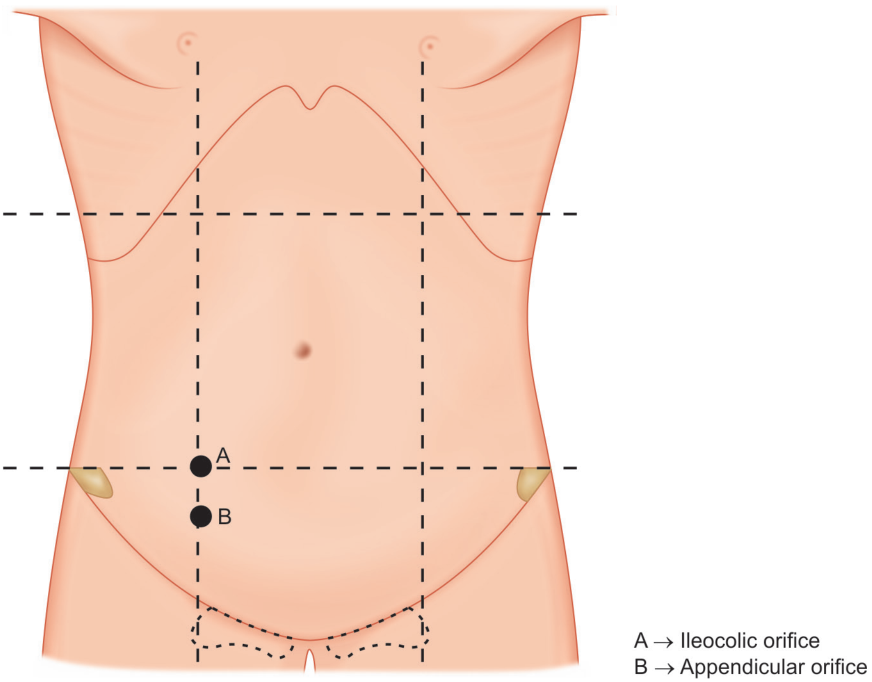


Fig. 3.10: Ileocolic orifice.

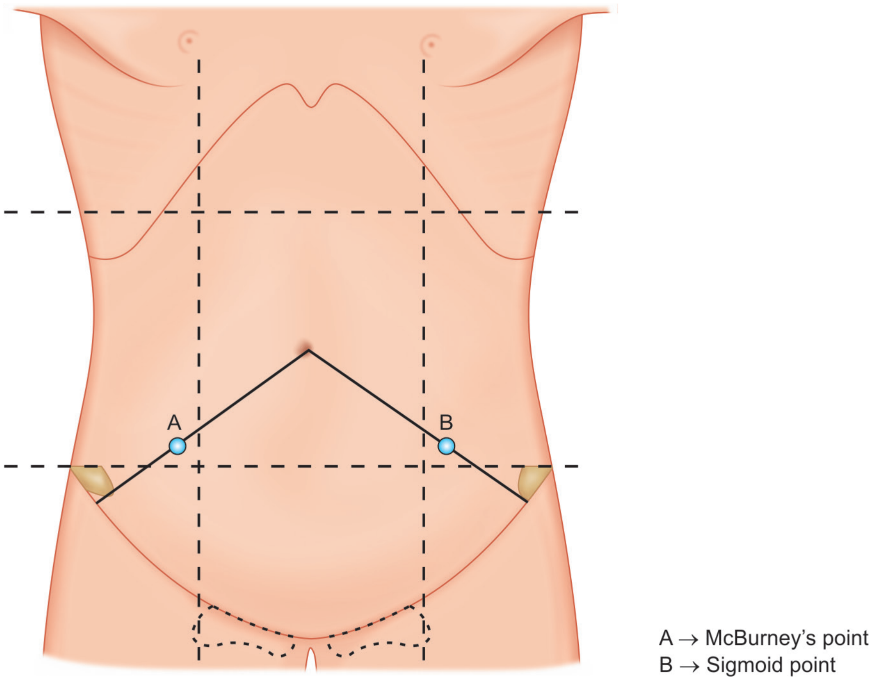


Fig. 3.11: McBurney's and sigmoid point.

Vermiform appendix: (Fig. 3.10)
The appendicular orifice is marked as a point 2 cms below the ileocolic orifice (B).

McBurney's point: (Fig. 3.11)

a. A line is drawn crossing the anterior superior iliac spine and umbilicus.
b. This is marked on the right side.
c. This is the spinoumbilical line.
d. The McBurney's point is at the junction of lateral one-third and medial two-thirds of the spinoumbilical line.

Applied Anatomy

The point marked as mentioned above is called McBurney's point. This is used to elicit pain due to appendicitis.

This surface anatomy is used for incision for appendectomy operation.

***Sigmoid point*:** The same corresponding point (as appendix) on the left side is called as the sigmoid point. It corresponds to the position of the sigmoid colon.

***Caecum (Fig. 3.12)*:** This is the beginning of the ascending colon. It is drawn on the right iliac fossa. A line is drawn from the anterior superior iliac spine to the upper border of the pubic symphysis. This line passes through the middle of the lower border of the caecum (AB).

***Ascending colon (Fig. 3.12)*:** This is present in the right iliac, lumbar and hypochondriac region. The right colic flexure lies at the junction of the right costal margin and the right lateral line.

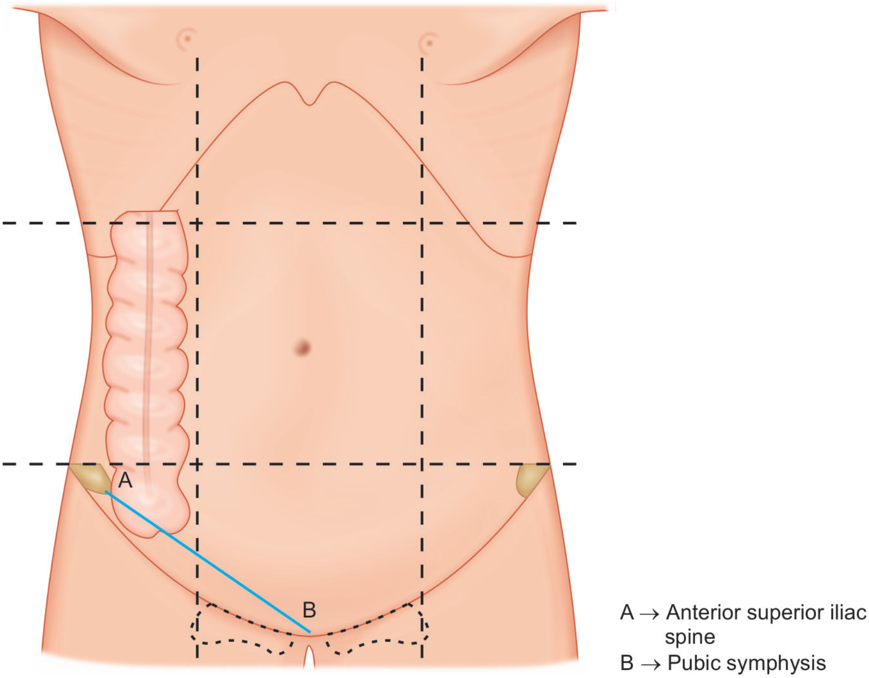


Fig. 3.12: Caecum and ascending colon.

***Transverse colon (Fig. 3.13)*:** It is present in the right and left hypochondriac, epigastric and umbilical regions. It extends from the right colic flexure and the left colic flexure. It is V shaped. The point of V lies in the umbilical region just above the umbilicus. The left colic flexure lies at the junction of the left lateral line and the transpyloric plane.

***Descending colon (Fig. 3.13)*:** It extends from the left colic flexure to the sigmoid colon. It lies in the left hypochondriac, lumbar and iliac regions. It lies lateral to the left lateral line.

Sigmoid Mesocolon (Fig. 3.14)

It is inverted V shaped.

a. Mark the midinguinal point (A).
b. Mark the junction of the transtubercular and left lateral plane (B).
c. Mark a point 2.5 cms medial to the above mentioned junction on the transtubercular plane (C).
d. Mark a point on the midline midway between the pubic symphysis and umbilicus (D).
e. Join A, C and D. This is the root of sigmoid mesocolon.

Applied Anatomy

Since the mesentry covering the sigmoid is relatively long and less fixed when compared to rest of the large intestine it can rotate over the axis of attachment of the mesentry in the left iliac fossa in a condition called Sigmoid "Volvulus" which is one of the causes for intestinal obstruction.

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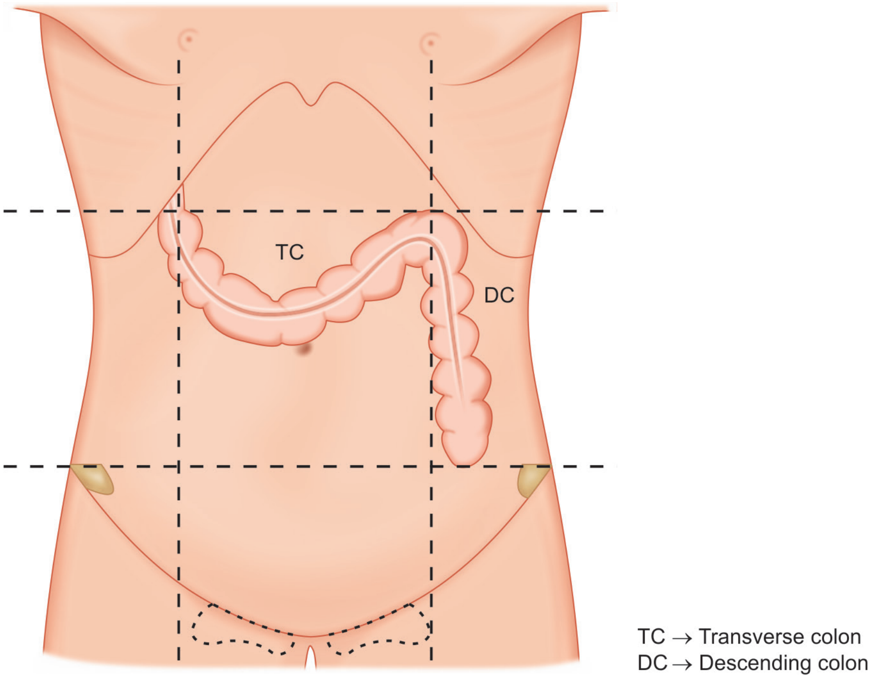

Fig. 3.13: Transverse and descending colon.

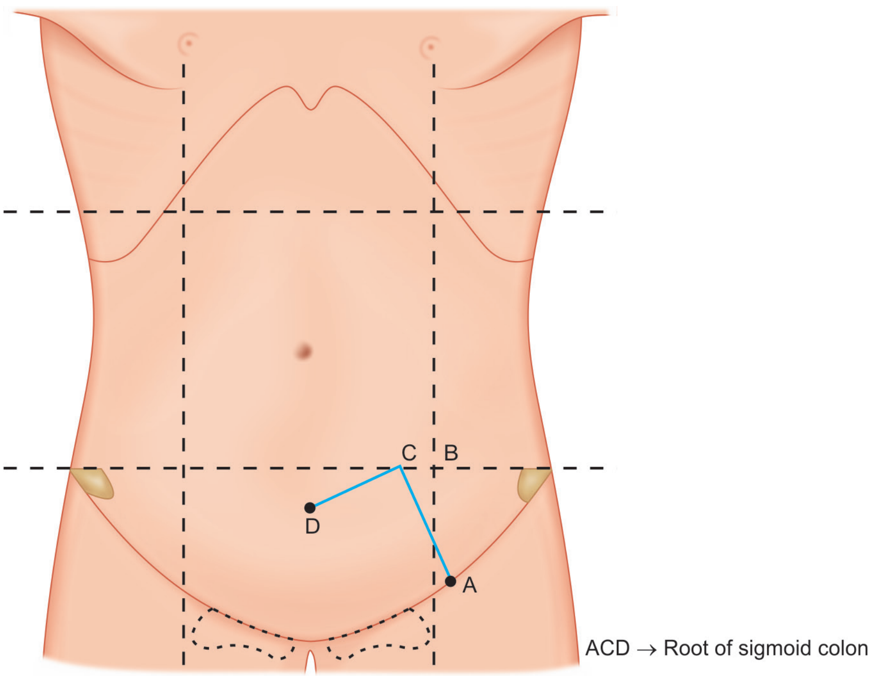

Fig. 3.14: Sigmoid mesocolon.

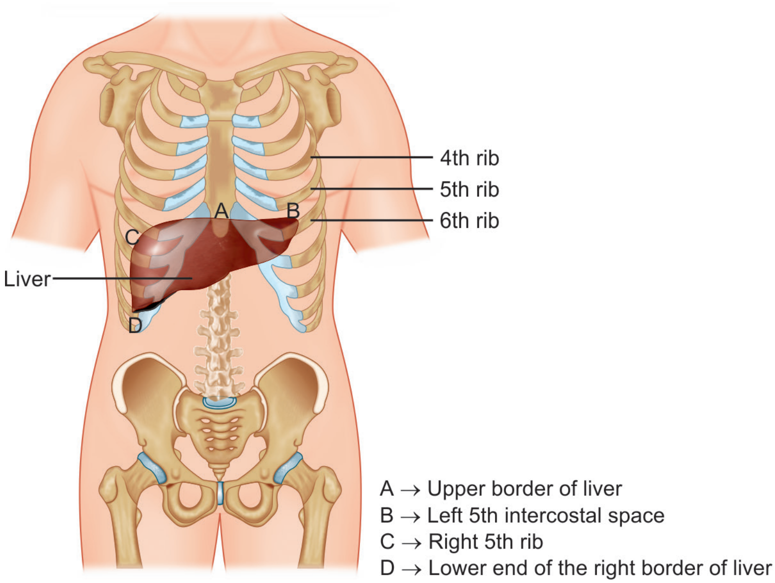

Fig. 3.15: Liver.

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The other common lesion involving the sigmoid which is amebic dysentery causes pain/ tenderness in the left iliac region.

The sigmoid colon is a common site for carcinomatous growths in the colon which can be palpable as a mass in the left iliac fossa (even sigmoid colon loaded with feces may sometimes be palpable as a mass in very lean individuals).

Liver (Fig. 3.15)

It is pyramidal in shape. It occupies right hypochondriac, epigastric and a small part of left hypochondriac regions. It is marked on the anterior aspect of the trunk.

***Lower border*:** Represented by an oblique line begins at the right costal margin at the tip if the right 9th costal cartilage, crosses mid line and another point at the tip of the left 8th costal cartilage and ends in the left 5th intercostal space in the midclavicular line (8–9 cm from the midline) (BD).

***Right border*:** From right 5th rib in the midclavicular line up to the lowest border of right costal margin in the midaxillary line (CD).

***Upper border*:** Indicated by a horizontal line just below the xiphisternal joint. The line extends to the left side up to the lower border of 5th rib and into the 5th intercostal space about 8–9 cm from the midline. Here it lies very close to the apex of the heart. The line extends to the right up to 5th rib in the midclavicular line (A/BC).

Most of the liver is concealed by the ribs, costal cartilages and diaphragm it is not palpable. Only the infrasternal part of the liver is palpable.

Applied Anatomy

The liver enlarges in a downward direction toward the right iliac fossa. Normally the liver is beneath the ribcage just in line with the subcostal margin. In order to palpate for liver, the palm is moved from the right iliac fossa to the right hypochondriac region. The palpation should be done during the inspiratory phase of respiration.

Common causes of hepatomegaly.

Infections like viral hepatitis, malaria, typhoid fever, HIV, tuberculosis, etc.

- Macronodular cirrhosis as in Alcoholics, fatty liver Hemoglobinopathies.
- Malignancies—Hepatocellular carcinoma, metastasis (distant spread) from other malignancies, Hematological malignancies such as lymphomas and leukemias.
- Infiltrative diseases such as Amyloidosis, Gaucher's disease, Niemann Pick disease, etc.
- Congestive hepatomegaly as in heart failure.

Gallbladder (Fundus) (Fig. 3.16): It is marked by a convex line at the tip of the 9th costal cartilage on the right side. The convexity of the line faces downwards (A).

Applied Anatomy

This point is used during clinical examination to elicit tenderness for cholecystitis (gallbladder inflammation). This sign of tenderness is called Murphy's sign. The palm of the hand should be kept in the right hypochondriac region beneath the right costal margin. The patient is asked to breathe deeply during palpation. On palpation, the patient will feel pain and catches his breath in case of acute cholecystitis.

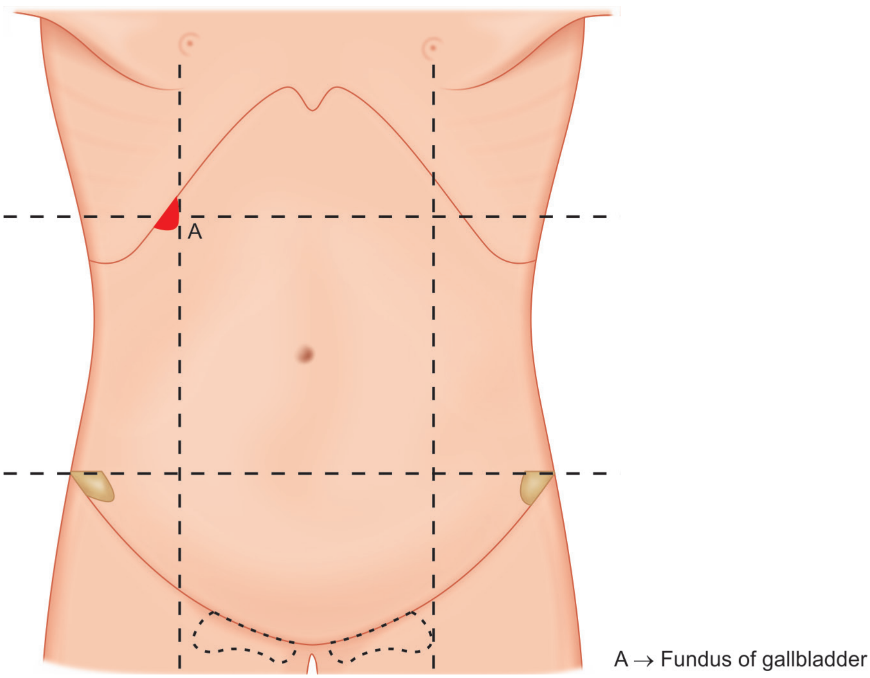

Fig. 3.16: Fundus of gallbladder.

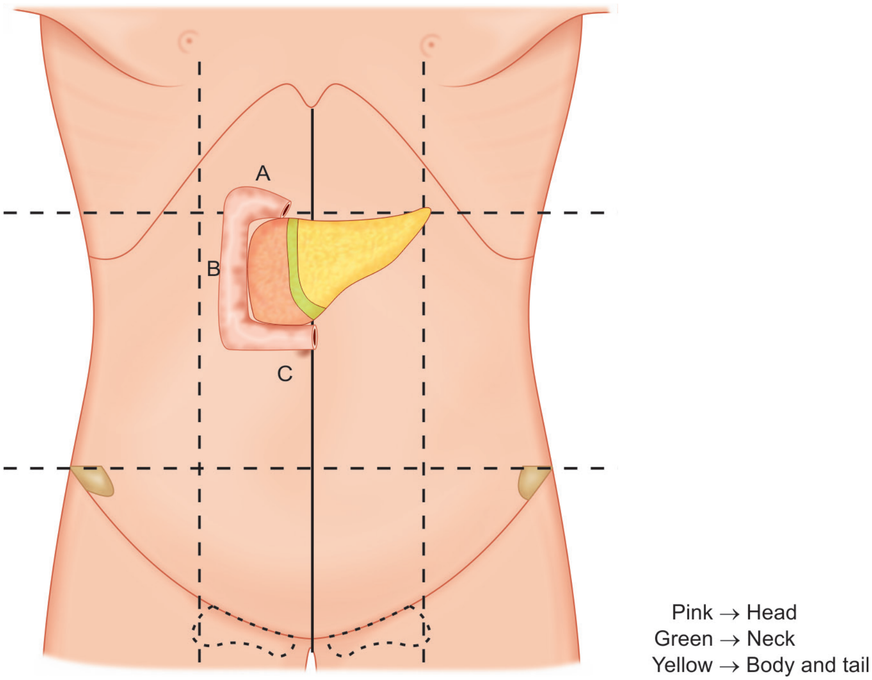

Fig. 3.17: Pancreas.

Pancreas (Fig. 3.17)

a. Mark the duodenum (ABC).
b. The space within the concavity of the duodenum represents the head of the pancreas.
c. Mark the pylorus of the stomach by marking a point 1.2 cms to the right of the midline just above the transpyloric plane. The neck of the pancreas lies vertically along this plane of pylorus.
d. Mark the body of pancreas by drawing two parallel lines about 3 cms apart tapering down as the lines move laterally for about 10 cms.
e. The end of this represents the tail which is situated lateral to the left lateral plane at its junction of the transpyloric plane.

Spleen (Fig. 3.18)

a. The spleen is marked on the back of the trunk.
b. The longitudinal axis of the spleen is drawn along the 10th rib.
c. The upper limit is upto the 9th rib and the lower limit of spleen is at the 11th rib.
d. The highest point is marked 4 cms lateral to the midline at the level 9th thoracic vertebra.
e. The lowest point lies in the midaxillary line at the level of the 1st lumbar spine.

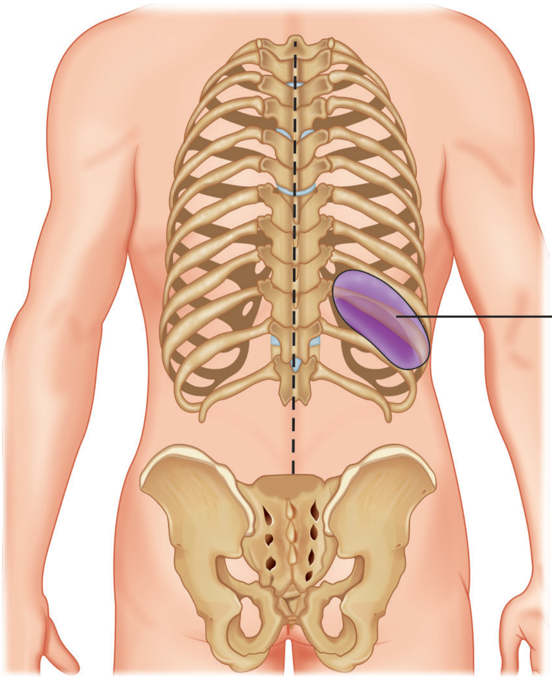

Fig. 3.18: Spleen.

Applied Anatomy

The Axis of spleen is along the axis of the 10th rib. This runs in the direction from the left hypochondriac region to the right iliac fossa. Hence enlargement of spleen should be examined in this direction. The palm is initially placed in the right iliac fossa and moved toward the left hypochondriac region. Splenic enlargement will be felt by the palm. The palpation must be gentle to avoid splenic injury as the organ is very fragile.

Spleen must be enlarged 2–3 times before it becomes palpable. Hence a mild splenomegaly where the spleen is still under the right costal margin can be detected by percussion. The various methods of percussing for the spleen are:

Traube's space dullness as described earlier.

Nixon's method: The patient is placed in the right lateral position and percussion begun at the lower level of lung resonance in the posterior axillary line moving diagonally anteriorly along a line perpendicular to the costal margin. The upper border of dullness is normally 6–8 cm above the costal margin. Dullness >8 cm in an adult usually indicates splenomegaly.

Castell's method: The patient is made to lie in supine position, percussion done in the 9th (lowest) intercostal space in the anterior axillary line produces a resonant note normally both during expiration or full inspiration. A dull percussion note on full inspiration suggests splenomegaly.

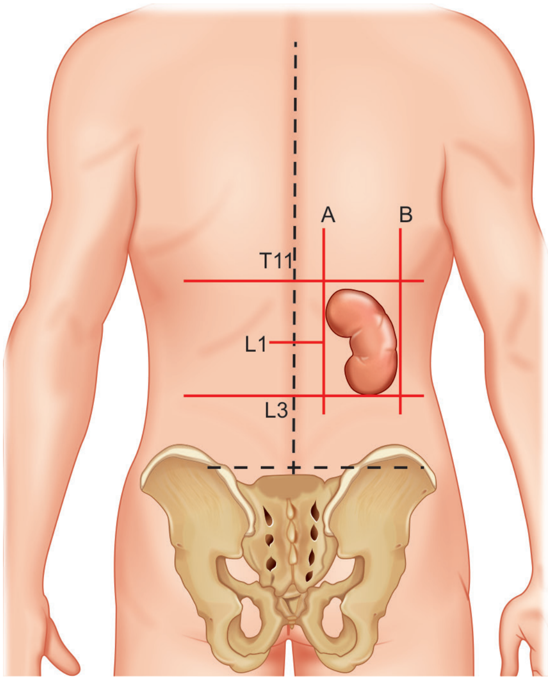

Fig. 3.19: Kidney.

Kidney (Fig. 3.19)

The kidneys are marked by the Morris parallelogram. This is marked by the following lines.

a. One transverse line at the level of the 11th thoracic spine.
b. Another transverse line at the level of 3rd lumbar spine.
c. One vertical line 2.5 cms from the midline.
d. Another vertical line is drawn 9.5 cms from the midline.

The kidney needs to be drawn as a bean shape with the following criteria. The upper pole is 2.5 cms away from the midline at the 11th thoracic spine. The hilum is 5 cms from the midline at the level of 1st lumbar spine. The lower pole is drawn 7.5 cms lateral to the midline at the level of 3rd lumbar spine.

This is the same for both the right and left kidneys.

Applied Anatomy

***Renal angle*:** This is the area between the 12th floating rib and the lateral border of the erector spinae. This area on palpation will elicit pain due to renal disease.

When palpating for the 12th rib, it should be done from above in order to prevent the considering of the 11th rib as 12th rib. This is important during renal exposure as the pleural cavity can be entered if the the rib is identified from below in cases of absent 12th rib. Then the 11th rib is thought as 12th rib and further procedure will lead to entering the pleural cavity leading to lung collapse.

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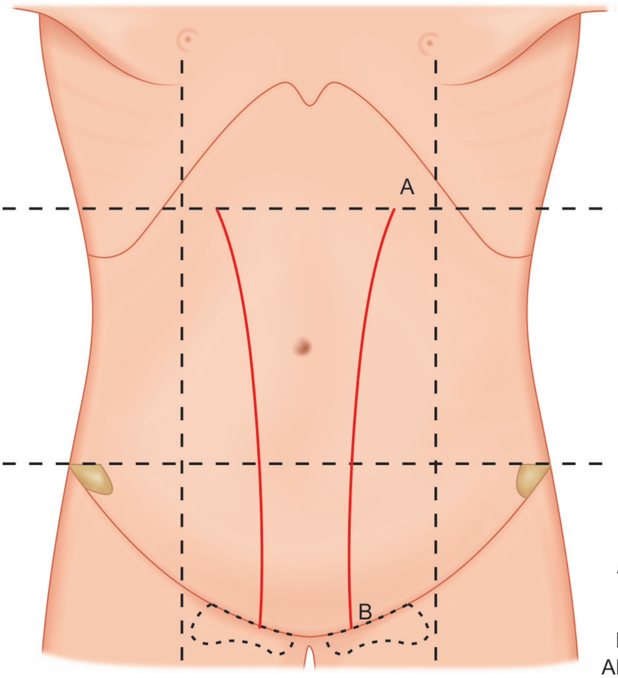

Fig. 3.20: Ureters.

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Tenderness at the renal angle may be present in conditions such as pyelonephritis (infection of the kidneys), renal calculi (stones in the kidney), severe obstruction of the urinary tract causing dilatation of the ureters and renal pelvis (hydroureteronephrosis).

Suprarenal Gland

The suprarenal glands are marked as triangular and semilunar shapes at the upper pole of the kidney on the right and left side respectively.

Ureters

For this the hilum of the kidney needs to be marked (Fig. 3.20).

On the front of the abdomen the hilum of kidney is marked 5 cm from the midline on the transpyloric plane. The ureter is drawn by a line from the hilum of the kidney (A) to the level of the pubic tubercle (B).

On the back, it is drawn from the hilum of the kidney through the posterior superior iliac spine.

Inferior Vena Cava (Fig. 3.21)

a. Mark the junction of transtubercular plane and the midline. Mark a point 2.5 cms to the right of the midline below this junction (A).

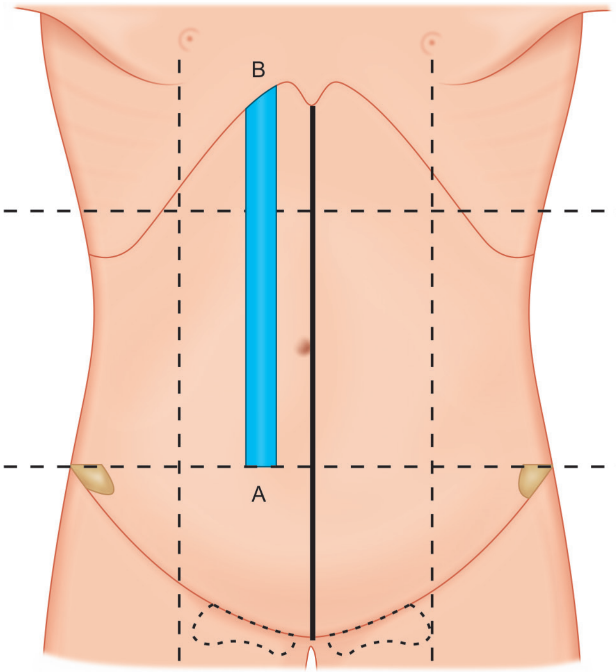


Fig. 3.21: Inferior vena cava.

b. Mark a point at the sternal end of the right 6th costal cartilage (B).
c. Mark two parallel lines 2.5 cms apart extending between the above mentioned points.

Portal Vein and Common Bile Duct (Fig. 3.22)

a. Mark the transpyloric and median planes.
b. Mark a point on the transpyloric plane about 1.5 cms to the right of the midline (B).
c. Mark a point at the midpoint of the 7th costal cartilage (C).
d. Join B and C by two parallel lines about 1.2 cm apart.
e. The ***Common bile duct*** is marked as two parallel lines 0.8 cm apart to the right of the portal vein. The length of the common bile duct is about 7.5 cms (green).

***Abdominal aorta (Fig. 3.23)*:** This is marked by two lines 2 cms apart. It extends from a point 4 cms above the transpyloric plane (A) to a point just below the umbilicus (line at the level of the tubercle of the iliac crests) (B) the lines are drawn left lateral to the midline.

Applied Anatomy

Abdominal aortic aneurysm when palpable can be felt as a pulsatile mass extending variably from the xiphoid process to the umbilicus close to the midline (*aneurysm* refers to a pathological dilatation of the normal vessel lumen involving one or several segments).

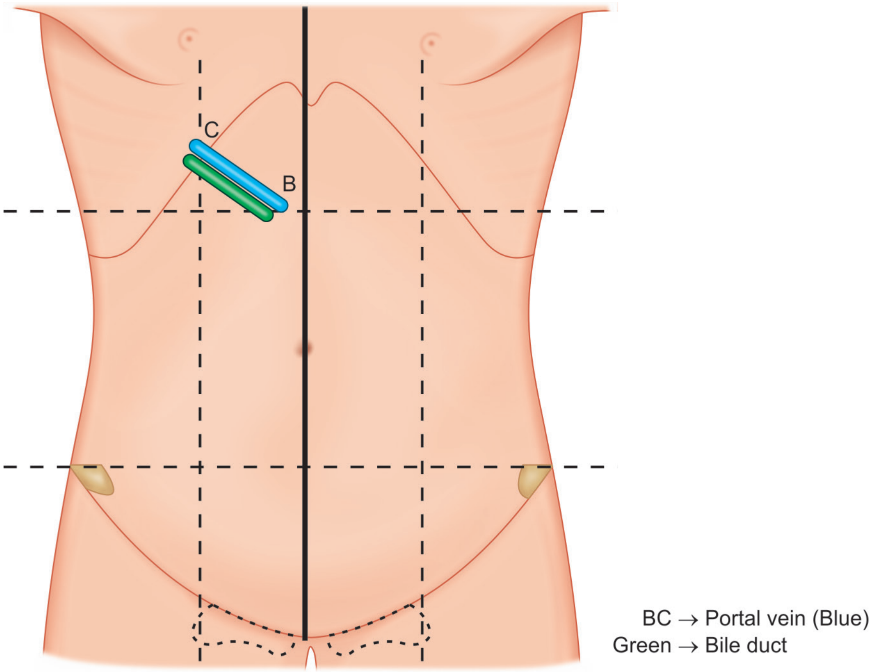


Fig. 3.22: Portal vein and bile duct.

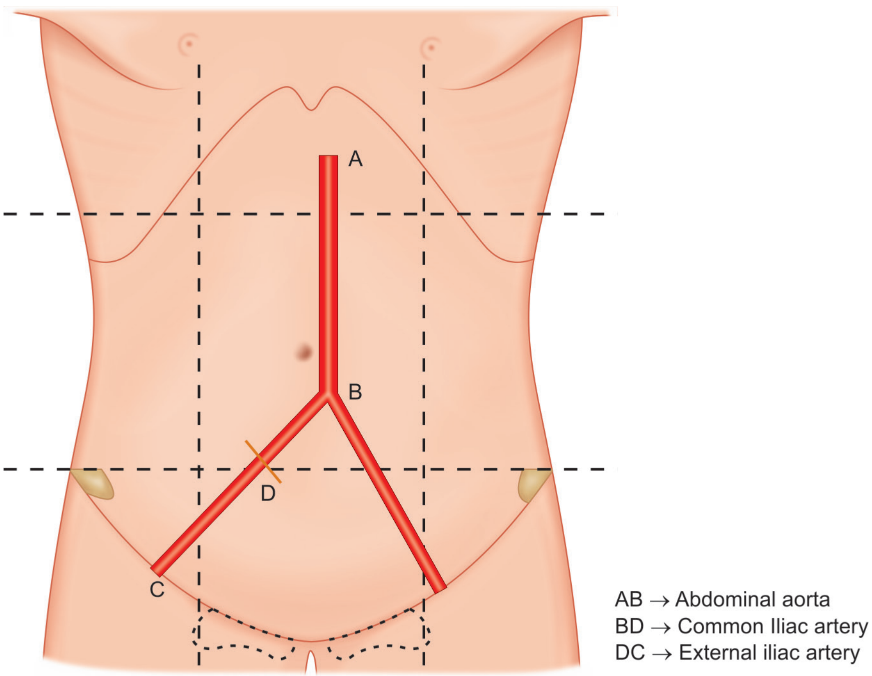


Fig. 3.23: Abdominal aorta and common iliac artery.

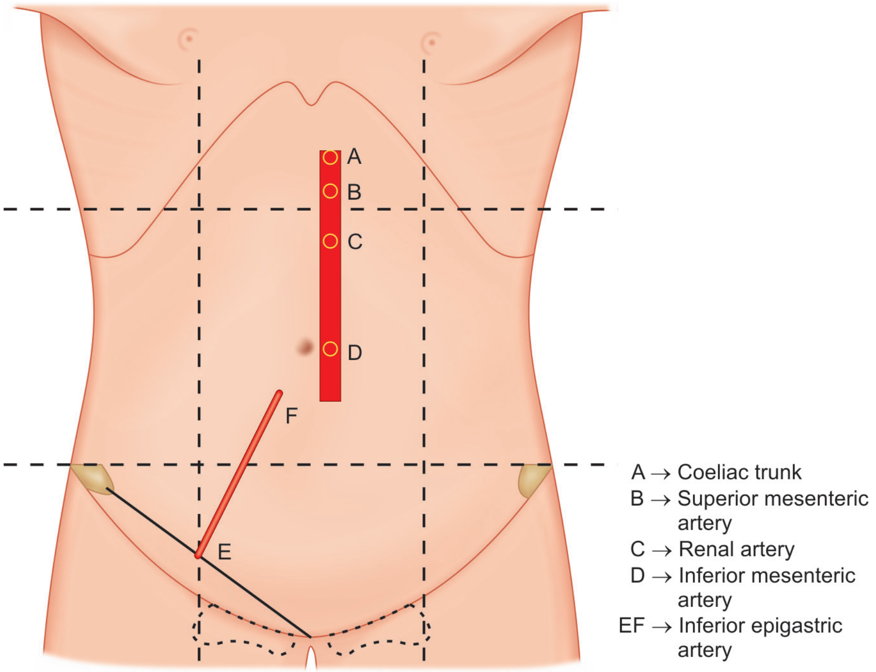


Fig. 3.24: Coeliac trunk, superior mesenteric artery and inferior mesenteric artery, renal artery and inferior epigastric artery.

***Common iliac artery (Fig. 3.24)*:** This is marked from the termination of abdominal aorta (B) to the point midway between the anterior superior iliac spine and pubic symphysis (C). The upper one third of this line represents the common iliac artery (BD) and lower two thirds represent the external iliac artery (DC).

The* coeliac trunk *(Fig. 3.24) is marked on the abdominal aorta 4 cms above the transpyloric plane.

The superior mesenteric artery (Fig. 3.24) is marked on the abdominal aorta 2 cms above the transpyloric plane.

The ***renal artery (Fig. 3.24)*** is marked 2 cms below the transpyloric plane.

The ***inferior mesenteric artery (Fig. 3.24)*** is marked 4 cms above the termination of the abdominal aorta at the level of transtubercular plane.

The ***inferior epigastric artery (Fig. 3.24)*** is marked by drawing a line from the anterior superior iliac spine and the pubic symphysis. A point is marked on the middle of the line (E). The line is extending from this midpoint to the umbilicus (F).

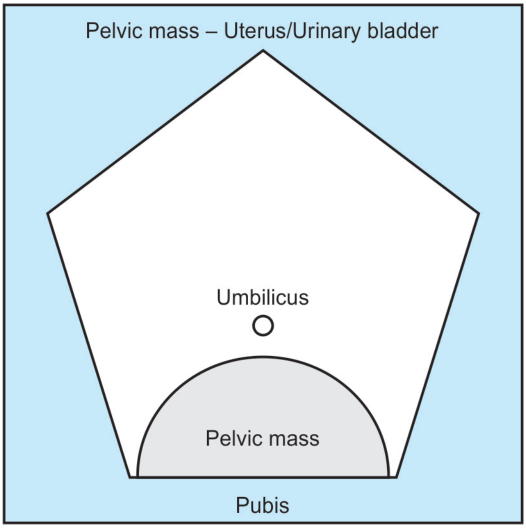


Fig. 3.25: Pelvic mass enlargement.

Pelvic Organs

- Urinary bladder
- Uterus
- Ovaries

These are not normally palpable but may become palpable when they enlarge and rise above the pelvis.

Urinary bladder and the uterus are midline structures and can be felt as supra pubic masses where only the upper margin is palpable and the lower margin is lying in the pelvis.

Ovarian masses on the other hand arise eccentrically out of the pelvis either on the right or the left iliac fossa region though this may be difficult to appreciate if the mass is very large.

Applied Anatomy

Enlarged urinary bladder may be caused by obstruction of the urethra due to urethral stricture idiopathic, secondary to pelvic radiotherapy, pelvic surgery, etc.

Posterior urethral valves

Uterine/pelvic mass pressing on the urethra

Enlarged uterus can be due to:

a. Pregnancy,
b. Uterine fibroids,
c. Malignancies of the uterus (Fig. 3.25).

4

Surface Anatomy of the Head and Neck

The bony landmarks are the following (Figs. 4.1 to 4.3):

a. Glabella is the area between the eyebrows
b. Superciliary arches is the prominences on the medial side of the eyebrows
c. Hairline is the border of the growth of hair on the scalp and temples
d. Zygoma is the prominences of the cheeks (malar eminences)
e. Zygomatic arch is a transverse arch formed by the processes of the zygoma and the temporal bones
f. Angle of mandible is the junction of the base and the ramus of the mandible
g. Base of mandible
h. Symphysis menti is the midpoint of the base of the mandible
i. External occipital protuberance is the prominence of the occipital bone
j. Superior nuchal line is the arched line from the external occipital protuberance

Fig. 4.1: Landmarks on the front of the head and neck.

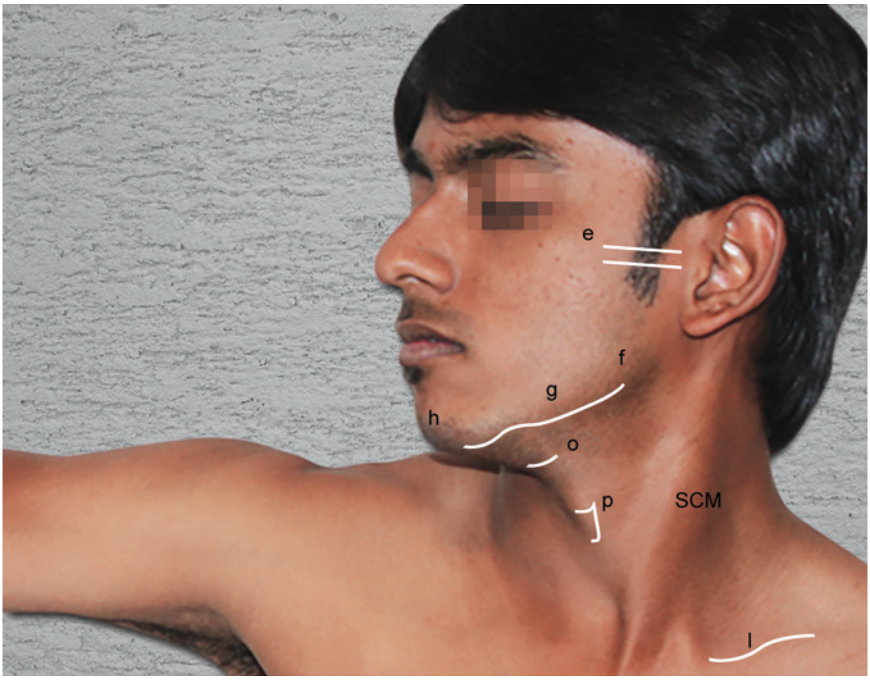


Fig. 4.2: Landmarks on the side of the head and neck.

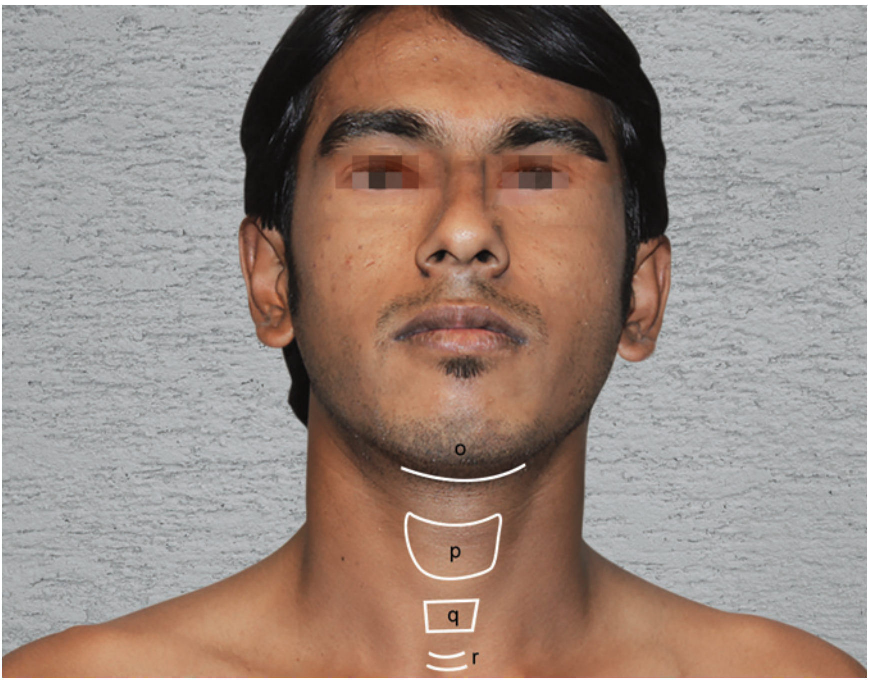
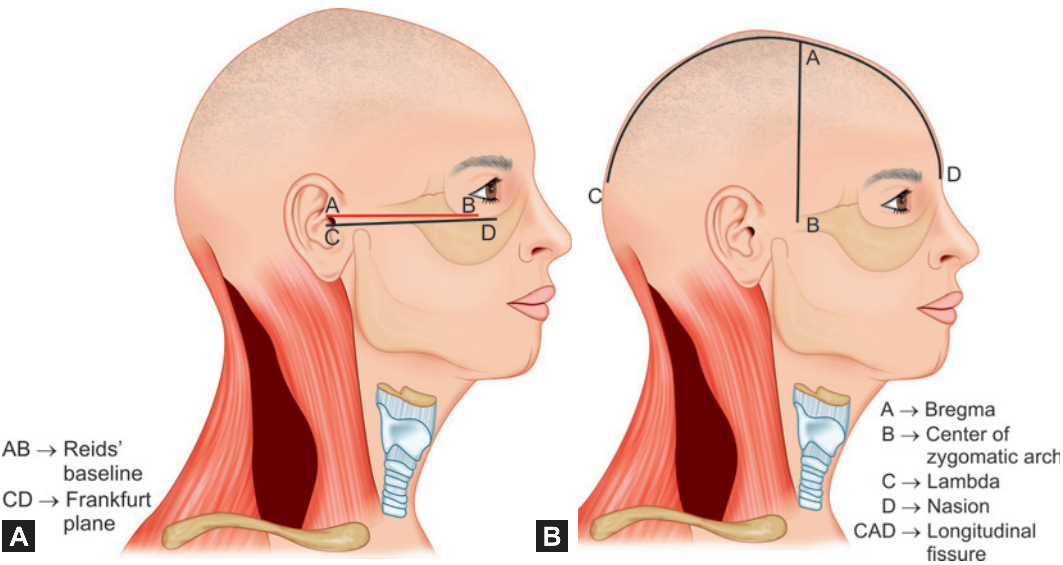


Fig. 4.3: Landmarks on the front of head and neck.

k. Vertebra prominence is due to spine of the 7th cervical vertebra
l. Clavicle
m. Suprasternal notch is the notch on the superior border of the manubrium sterni
n. Supraorbital notch is the notch on the medial aspect of the supraorbital margin
o. Hyoid bone
p. Thyroid cartilage
q. Cricoid cartilage
r. Tracheal rings
s. Pterion is an area where the temporal, greater wing of sphenoid, frontal and parietal bones articulate
t. Asterion is the posterior end of parietomastoid suture
u. Inion is the highest point of the external occipital protuberance
v. Lambda is the point where the sagittal and lambdoid sutures meet
w. Bregma is the point where the sagittal and coronal sutures meet
x. Mastoid process
y. ***Reid's base line*:** It is a line along the lower margin of the orbit to the upper border of external auditory meatus (Fig. 4.4A).
z. ***Frankfurt's plane*:** This plane is along infraorbital margin through midpoint of external acoustic meatus (Fig. 4.4A).
aa. Coronal suture is the line from the bregma and the center of the zygomatic arch on both sides (Figs. 4.4B and 4.5).
bb. Sagittal suture is the line drawn from the bregma to the lambdoid suture (Fig. 4.4B)
cc. Lambdoid suture is upper two-thirds of the line from the lambda to the mastoid process.

***The soft tissue land marks are*:** External ear and tragus, sternocleidomastoid.



Figs. 4.4A and B: (A) Reid's baseline Frankfurt's plane. (B) Longitudinal fissure.

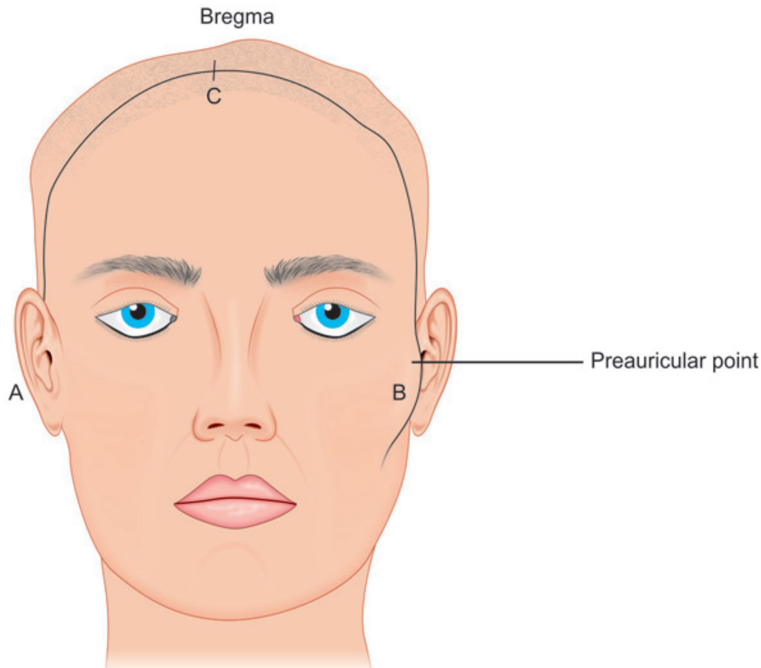


Fig. 4.5: Coronal suture.

Surface Anatomy of Brain

The ***longitudinal fissure*** corresponds to line extending from the nasion to the inion (Fig. 4.4B).

Lateral Sulcus (Sylvian Fissure) (Fig. 4.6)

The ***posterior ramus*** (AB) of lateral fissure extends from the sylvian point to a point 2 cms below the parietal eminence. The sylvian point is marked 3.5 cms behind and 1.2 cms above the frontozygomatic suture (A).

The ***anterior ascending ramus*** is marked by a line 2 cms which runs upward from the sylvian point (AC).

Another line of 2 cms length from the sylvian point forwards and horizontally will mark the ***anterior horizontal ramus*** (AD).

***Parieto-occipital sulcus*:** This sulcus is marked by drawing a line perpendicular to the median longitudinal fissure at about 5 mm in front of the lambda (F). This line runs for about 2.5 cms (GH).

Central Sulcus (Fig. 4.7)

1. A point 1.25 cms behind the center of the line extending from the nasion to the inion.
2. A line perpendicular to the reid's base line at the preauricular point.

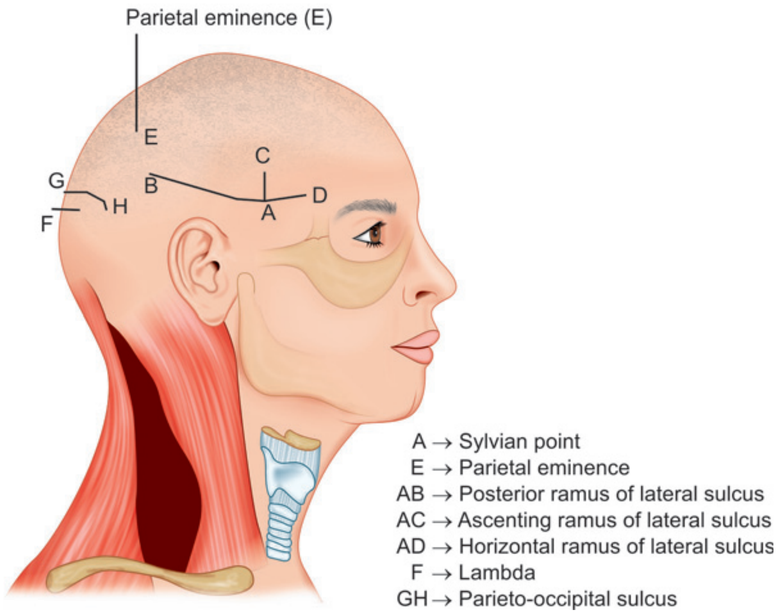


Fig. 4.6: Posterior ramus, ascending and anterior horizontal ramus of lateral sulcus and parieto-occipital sulcus.

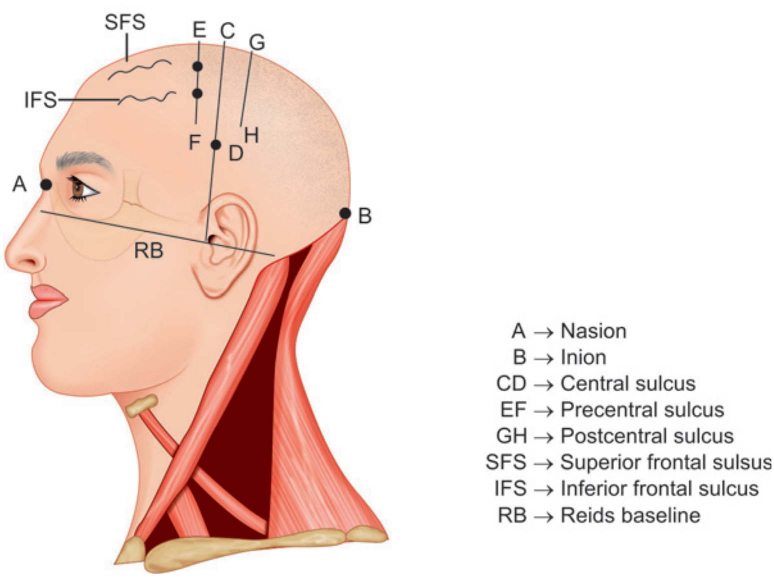


Fig. 4.7: Showing central, precentral, postcentral, superior frontal and inferior frontal sulcus.

3. The first point and the 3rd point are joined by a line.
4. The upper 9 cms of this line marks the central sulcus (CD).

The ***precentral sulcus*** and the ***postcentral sulcus*** is drawn 1.5 cms in front and behind the central sulcus. They lie parallel to the central sulcus (Fig. 4.7) (EF and GH).

Lateral Ventricle (Fig. 4.8)

1. One horizontal line 5 cms above the zygomatic arch. (roof of the lateral ventricle) (AB).
2. Another horizontal line 1 cm above the zygomatic arch (inferior horn) (CD).
3. One vertical line through the junction of anterior and middle thirds of the zygomatic arch. (anterior horn) (EF).
4. One vertical line 5 cms behind the tip of the mastoid process (posterior horn) (GH).

Superior Frontal Sulcus (Fig. 4.7)

It is drawn by marking a line from the junction of the upper and middle third of the precentral sulcus.

Inferior Frontal Sulcus (Fig. 4.7)

The inferior frontal sulcus is at the junction of the middle and lower one-third of the precentral sulcus.

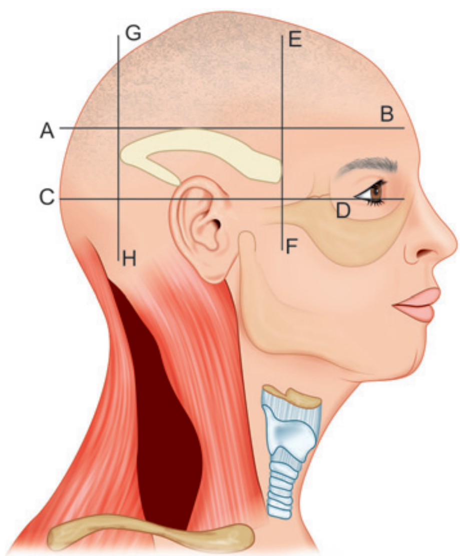


Fig. 4.8: Lateral ventricle.

Superior Temporal Sulcus (Fig. 4.9A)

Draw a line 1 cm below and parallel to posterior ramus of the lateral sulcus.

Motor speech area *(Fig. 4.9A)*: Marked by an oval area 4 cms above the midpoint of the zygomatic arch.

Motor area *(Fig. 4.9A)*: The gap between the central sulcus and the precentral sulcus is the precentral gyrus representing the motor area.

Sensory area *(Fig. 4.9A)*: The gap between the central sulcus and the postcentral sulcus is the postcentral gyrus representing the sensory area.

Auditory area *(Fig. 4.9A)*: The gap between the posterior ramus of the lateral sulcus and superior temporal sulcus is the superior temporal gyrus. The posterior part of the gyrus represents the auditory area which is corresponds to the upper border of auricle.

Visual area *(Fig. 4.9A)*: The area is located just above and lateral to external occipital protuberance.

Superior Sagittal Sinus (Fig. 4.9B)

a. Mark a point on the glabella.
b. Mark a point on the inion.
c. Join the point a to b by two lines which widen as they reach the point B. The maximum width to be 1.2 cms.

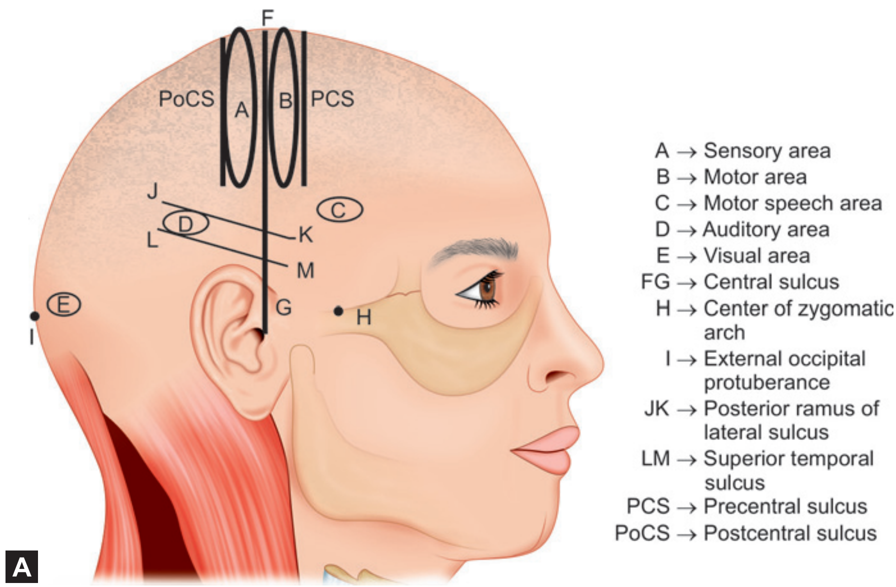


Fig. 4.9A: Motor, sensory, speech, visual and auditory functional areas.

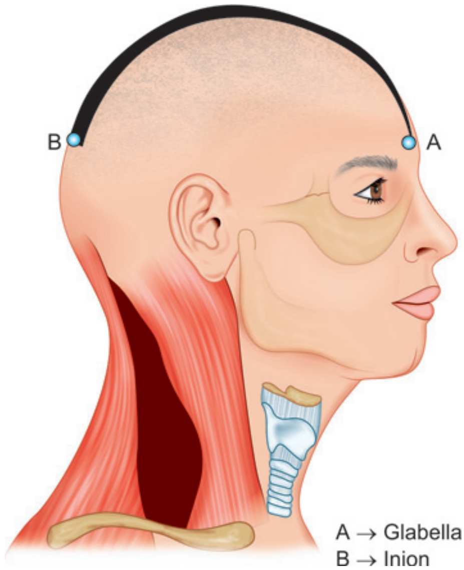


Fig. 4.9B: Superior sagittal sinus.

HEAD AND NECK

Parotid Gland (Fig. 4.10A)

This appears like a tetrahedron.

a. The superior border is along the lower margin of the posterior two-thirds of the zygomatic arch.
b. The posterior border runs in front of the external acoustic meatus and the mastoid process and the anterior border of the sternocleidomastoid.
c. The anterior border spans over the masseter muscle for a variable distance.

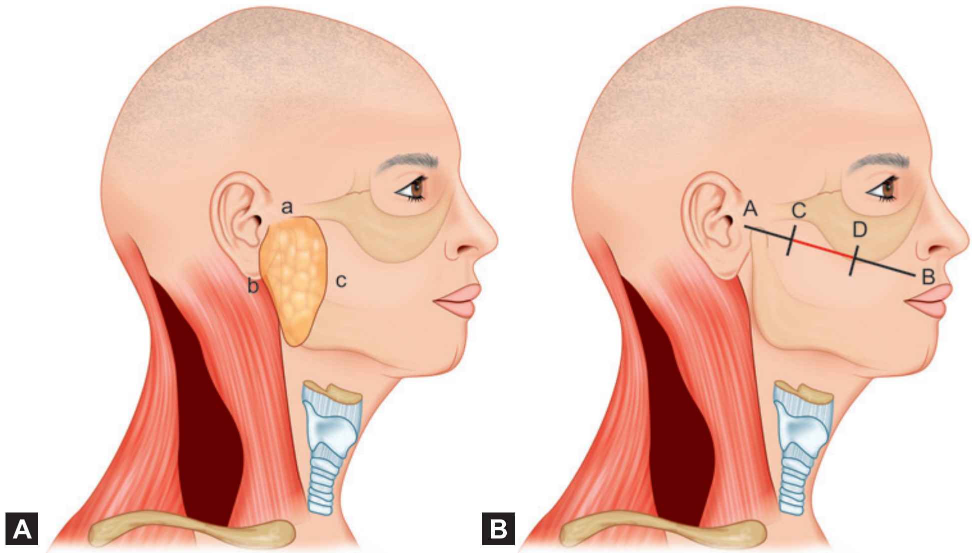
Parotid Duct (Fig. 4.10B)

a. A line extending from the external acoustic meatus (A) to a point midway between the ala of the nose and the lateral angle of the mouth (B).
b. The middle one-third of this line is the parotid duct (CD).
c. Here it pierces the buccinators to open into the vestibule of the mouth at the level of the crown of the 2nd upper molar tooth.

Frontal Sinus (Fig. 4.11)

The following points are marked.

a. Nasion is marked (A).
b. A point 3 cms above the nasion in the midline (B).
c. A point at the junction of the medial and middle thirds of the supraorbital margin (C).



Figs. 4.10A and B: Parotid gland and duct.

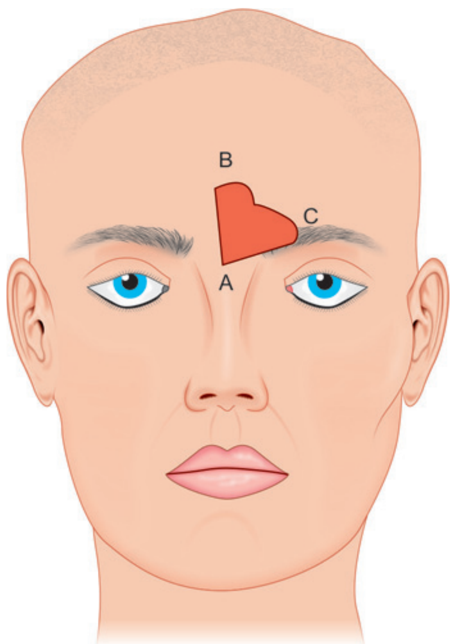


Fig. 4.11: Frontal air sinus.

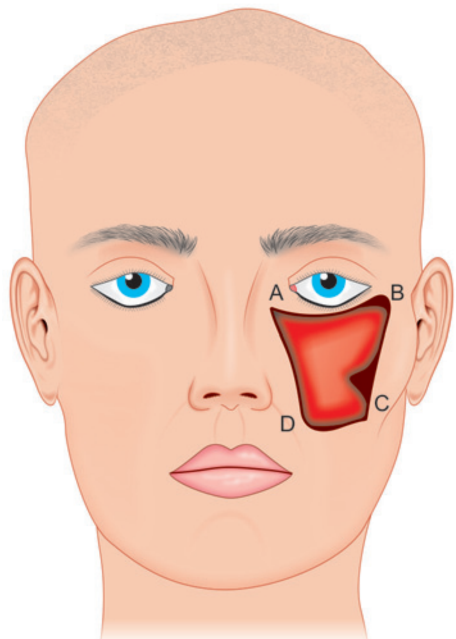


Fig. 4.12: Maxillary air sinus.

Maxillary Sinus (Fig. 4.12)

The sinus is quadrilateral in shape. It is marked by the following points.

a. Lacrimal tubercle (A).

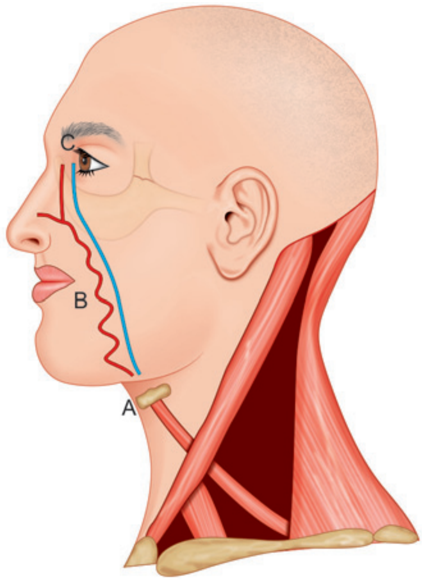


Fig. 4.13: Facial artery and vein.

b. Junction of the lateral and inferior margins of the orbit (B).
c. Point on the upper last molar in the maxilla (C).
d. Point on the upper second premolar in the maxilla (D).

Facial Artery (Fig. 4.13)

a. Along the base of the mandible at the anteroinferior border of the masseter. This is marked by measuring 3.5 cms anterior to the angle of mandible (A).
b. A point 1.2 cms lateral to the angle of the mouth (B).
c. Angle of the eye (C).
d. Join A, B and C by a tortuous line.

Facial Vein (Fig. 4.13)

It is marked as a straight line behind the facial artery.

Applied Anatomy

The facial artery is palpated regularly by anesthetists for pulsations which indicates the blood flow. Hence known as anesthetist's artery.

The cosmetic surgeons inject fillers near the angle of the eye for filling the sagging tear trough which increase with age. During this procedure care should be taken not to enter the facial artery at the angle of the eye. As fillers can act as emboli and by retrograde flow can block the central artery of retina leading to complete blindness.

The same can happen during injection of fillers near the nasolabial fold.

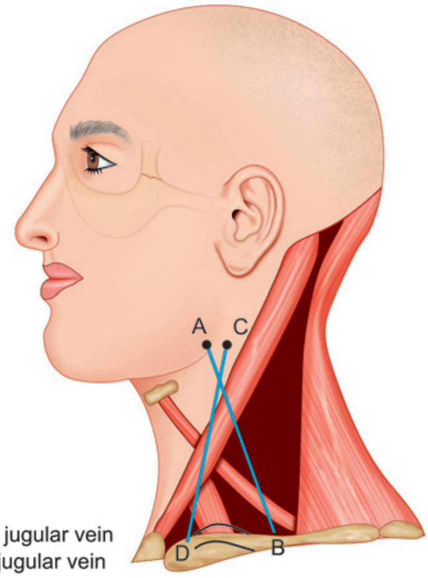


Fig. 4.14: External jugular vein and internal jugular vein.

External Jugular Vein (Fig. 4.14)

a. Point at the angle of the mandible (A).
b. Point at the middle of the clavicle (B). Join points A and B.

Applied Anatomy

External jugular vein needs to be identified in order to visualize the level of pulsations for jugular venous pressure measurement.

Jugular venous pressure gains its importance to understand the status of right atrium. It is of importance in diseases like pulmonary hypertension, tricuspid regurgitation and constrictive pericarditis.

Internal Jugular Vein (Fig. 4.14)

c. A point behind the angle of the mandible (C).
d. Another point at the sternal end of the clavicle (D).
e. Join points C and D.

Common Carotid Artery (Fig. 4.15)

a. A point at the medial end of the clavicle (A).
b. A point at the level of upper border of the thyroid cartilage along the anterior border of Sternocleidomastoid (B).
c. Join points A and B.

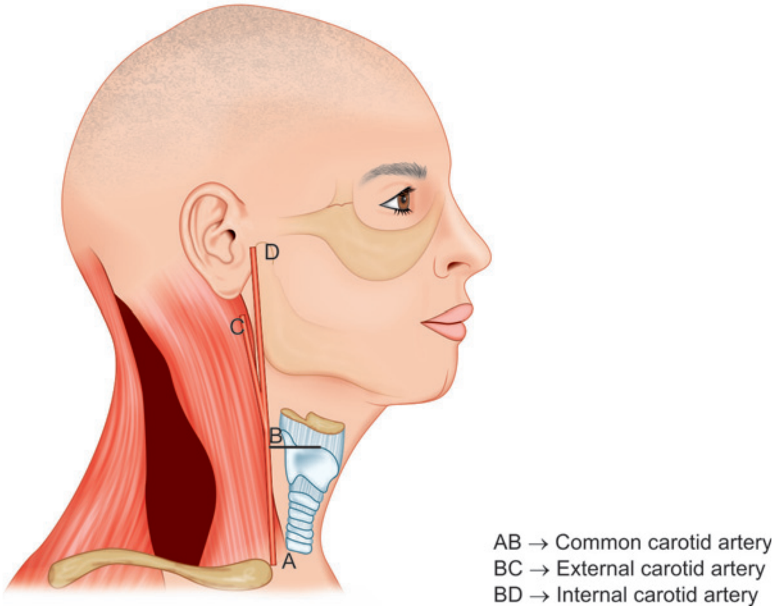


Fig. 4.15: Common carotid, internal and external carotid artery.

Applied Anatomy

The common carotid artery is used to palpate for pulsations. It is felt at the level of cricoid cartilage between the larynx and the sternocleidomastoid muscle. The pulse is felt for diagnosis of cardiac valvular diseases and post trauma to confirm death.

The common carotid artery is also located to compress during scalp hemorrhage to prevent blood loss. The compression is done against the chassaignac's tubercle (anterior tubercle of 6th cervical vertebra)

The common carotid artery is also accessed by dissection for cannulation during embalming for cadaver preservation.

External Carotid Artery (Fig. 4.15)

a. A point at the level of upper border of the thyroid cartilage along the anterior border of sternocleidomastoid (B).
b. A midpoint between the mastoid process and the angle of the mandible (C).
c. Join points B and C.

Internal Carotid Artery (Fig. 4.15)

a. Mark a point at the level of upper border of thyroid cartilage along the anterior border of sternocleidomastoid (B).
b. Mark a point at the posterior border of the mandibular condyle (D).
c. Join points B and D.

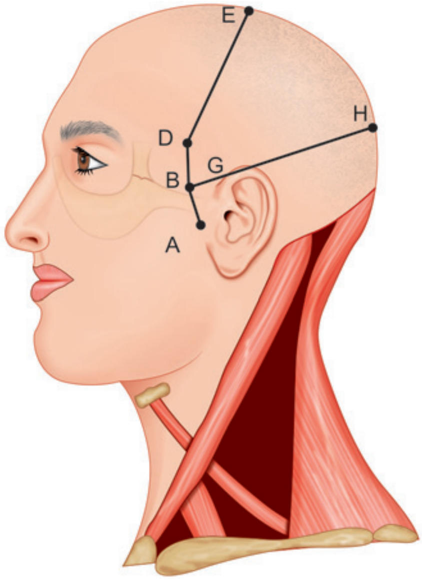


Fig. 4.16: Middle meningeal artery.

Middle Meningeal Artery (Fig. 4.16)

This is marked as the trunk, anterior and posterior division by the following points:

Trunk

a. A point at the pre-auricular point (A).
b. A point 2 cms above it (B).
c. Join points A and B to mark the trunk.

Anterior Division

d. Point on the Pterion (D).
e. Point on the midpoint of the line connecting the inion and the nasion (E).
f. Join B, D, and E.

Posterior Division

g. A point at the superior attachment of the auricle (G).
h. A point on the lambda (H).
i. Join B, G, and H.

Applied Anatomy

The middle meningeal artery is approached through the area of pterion in order to control extradural hemorrhage. Usually the extra dural hemorrhage is due to rupture of middle meningeal vessels.

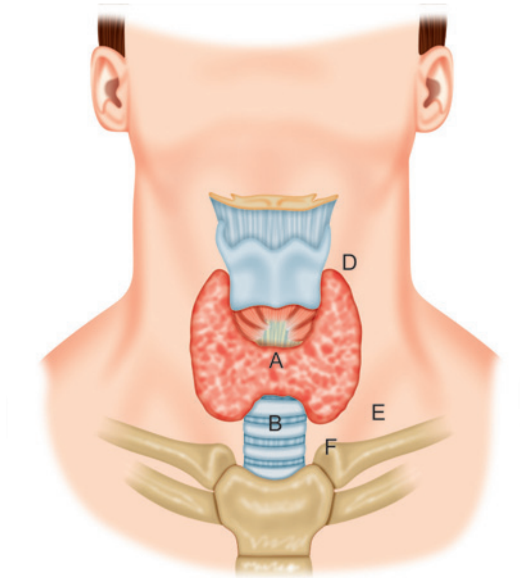


Fig. 4.17: Thyroid gland.

THYROID GLAND (FIG. 4.17)

Isthmus

a. A line is drawn 1 cm below the arch of the cricoid cartilage (A).
b. Another line is drawn 2 cm below the arch of the cricoids cartilage (B).
c. The space between the two lines marks the isthmus running over the trachea.

Lateral Lobe

d. A point along the anterior border of sternocleidomastoid at the level of the laryngeal prominence (D).
e. A point 2.5 cm below and lateral to the lower border of the isthmus of the thyroid gland (E).
f. A point 1 cm below the lateral end of the lower border of the isthmus (F).
g. Join D, E and F to the isthmus to mark the lateral lobe on both sides.

Applied Anatomy

The thyroid swellings (Goiter) is the most common swelling in the midline of the neck. The thyroid gland can be palpated in between the two sternocleidomastoid muscles upto the level of thyroid cartilage.

The isthmus of the thyroid is usually retracted up in order to access the trachea for emergency procedures like tracheostomy. The location of the isthmus helps in the incision.

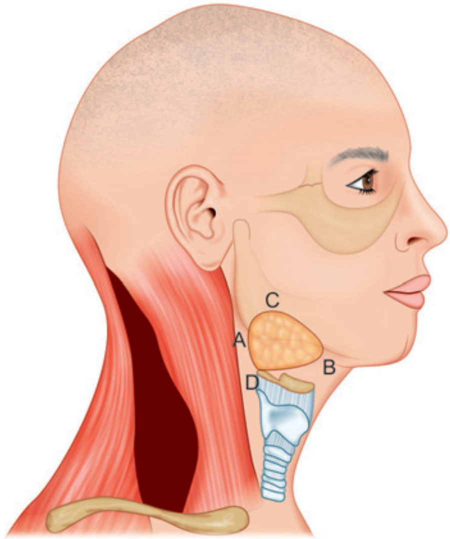


Fig. 4.18: Submandibular gland.

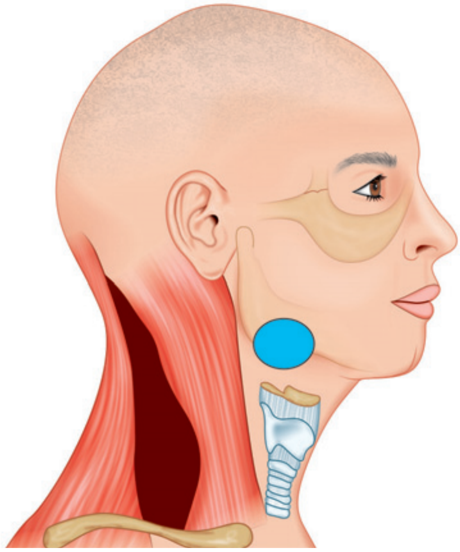


Fig. 4.19: Tonsil.

Submandibular Gland (Fig. 4.18)

a. A point below the angle of the mandible (A).
b. A point midway between the angle of the mandible and the symphysis menti (B).
c. A point about 1.5 cms above the angle of the mandible (C).
d. A point near the posterior end of the tip of the greater cornu of the hyoid bone (D).

Join points ABCD to mark the submandibular gland.

Tonsil (Fig. 4.19): A oval outline over the masseter just above the angle of the mandible.

Suprameatal Triangle (Fig. 4.20)

a. Line above the posterior root of the zygomatic arch (A).
b. Line tangential to the posterior border of the external acoustic meatus (B).
c. A perpendicular line from line A along the posterior border of the external acoustic meatus (C).

Applied Anatomy

The suprameatal triangle forms the lateral wall of the mastoid antrum. This can be felt as a triangular depression through the cymba conchae of the external ear. This approach is used to gain access to the mastoid antrum during surgical debridement of mastoid abscess.

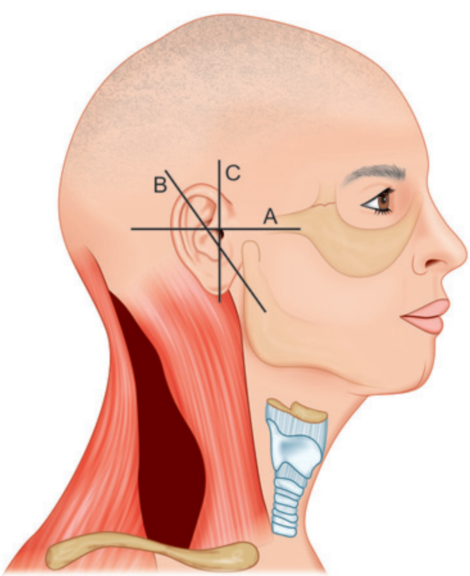


Fig. 4.20: Suprameatal triangle.

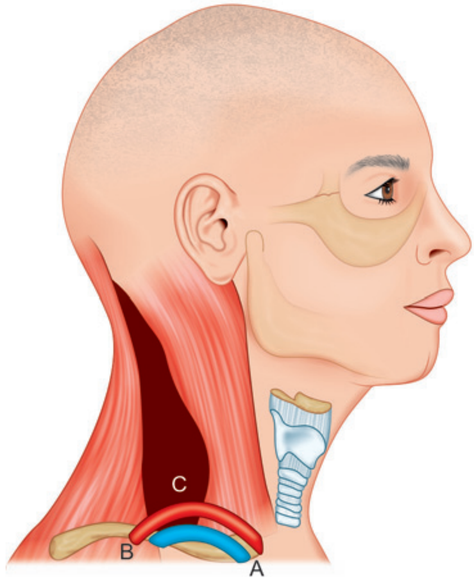


Fig. 4.21: Subclavian vessels.

Subclavian Vessels (Fig. 4.21)

a. Mark the sternoclavicular joint (A).
b. Mark the middle of the lower border of the clavicle (B).
c. Mark 2 cms above the clavicle midway between A and B, (C).
d. Join A, B and C to mark the subclavian artery by two parallel line 1cm apart.
e. The subclavian vein lies within the concavity of the artery.

Applied Anatomy

The Right Subclavian vein is commonly catheterized to monitor the central venous pressure (pressure in the right atrium), to insert chemotherapy ports or permanent dialysis catheter (ports kept in the vein for many months for the purpose of giving long term drugs like cancer drugs, for doing dialysis, etc). The anatomic landmarks-beginning with the middle third of the clavicle follow laterally to the point where the clavicle deviates from the proximal ribs. Just medial to this point, the subclavian vein and artery run just inferior to the clavicle. Here a trocar and cannula are inserted parallel to the clavicle at a slight angulation to the skin to locate the subclavian vein.

Vocal Cords

Mark a point on either sides of the laryngeal prominence. This indicates the anterior attachments of the vocal cords.

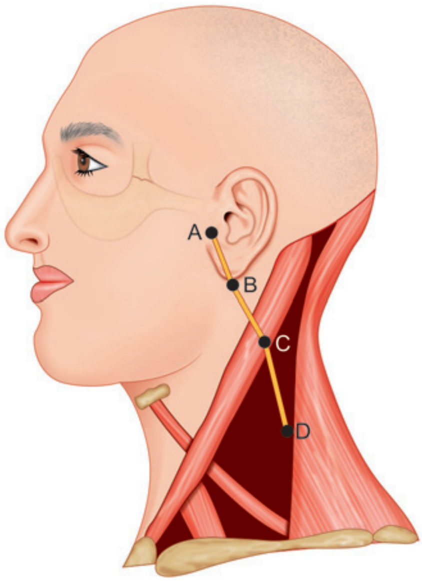


Fig. 4.22: Accessory nerve.

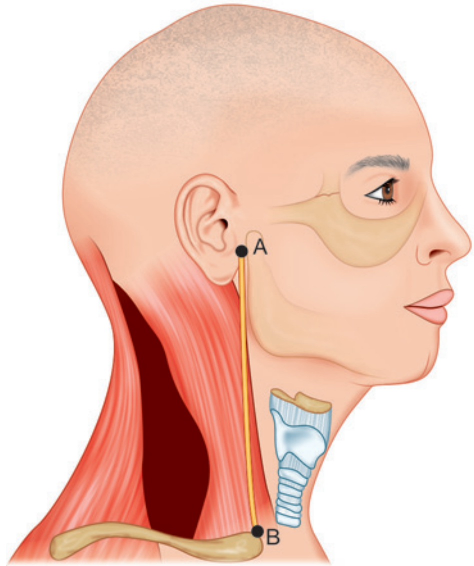


Fig. 4.23: Vagus nerve.

CRANIAL NERVES

Accessory Nerve (Fig. 4.22)

a. A point anterior to the tragus (A).
b. A point at the tip of the transverse process of the atlas (B).
c. A point along the posterior border of the sternocleidomastoid muscle at the junction of upper one-third and lower two-thirds of the muscle (C).
d. A point along the anterior border of the trapezius about 6 cms above the clavicle (D).

Vagus Nerve (Fig. 4.23)

a. A point antero-inferior to the tragus (A).
b. A point on the sternal end of the clavicle (B).
c. Join AB.

Glossopharyngeal Nerve (Fig. 4.24)

a. A point anterior to the tragus (A).
b. A point just above the angle of the mandible (B).

Hypoglossal Nerve (Fig. 4.25)

a. A point anteroinferior of the tragus (A).
b. A point above and behind the tip of the greater cornu of the hyoid bone (B).

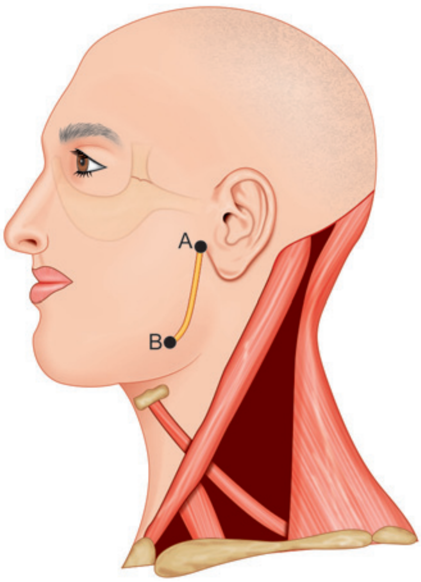


Fig. 4.24: Glossopharyngeal nerve.

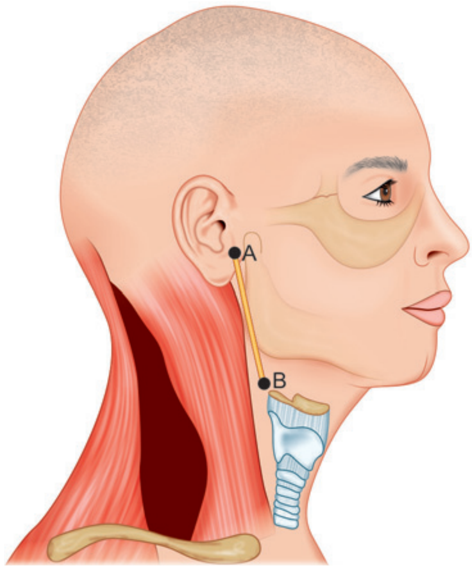


Fig. 4.25: Hypoglossal nerve.

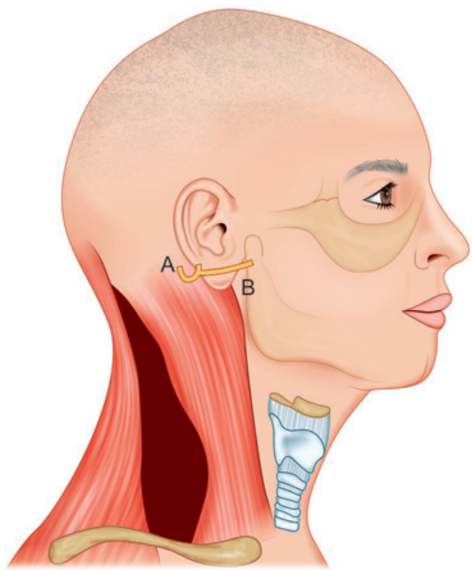


Fig. 4.26: Facial nerve.

Facial Nerve (Trunk of the Extracranial Part) (Fig. 4.26)

a. A point at the middle of the anterior border of the mastoid process (A).
b. A point on the upper part of the lobule of the ear (B).

Surface Anatomy of the Upper Limb

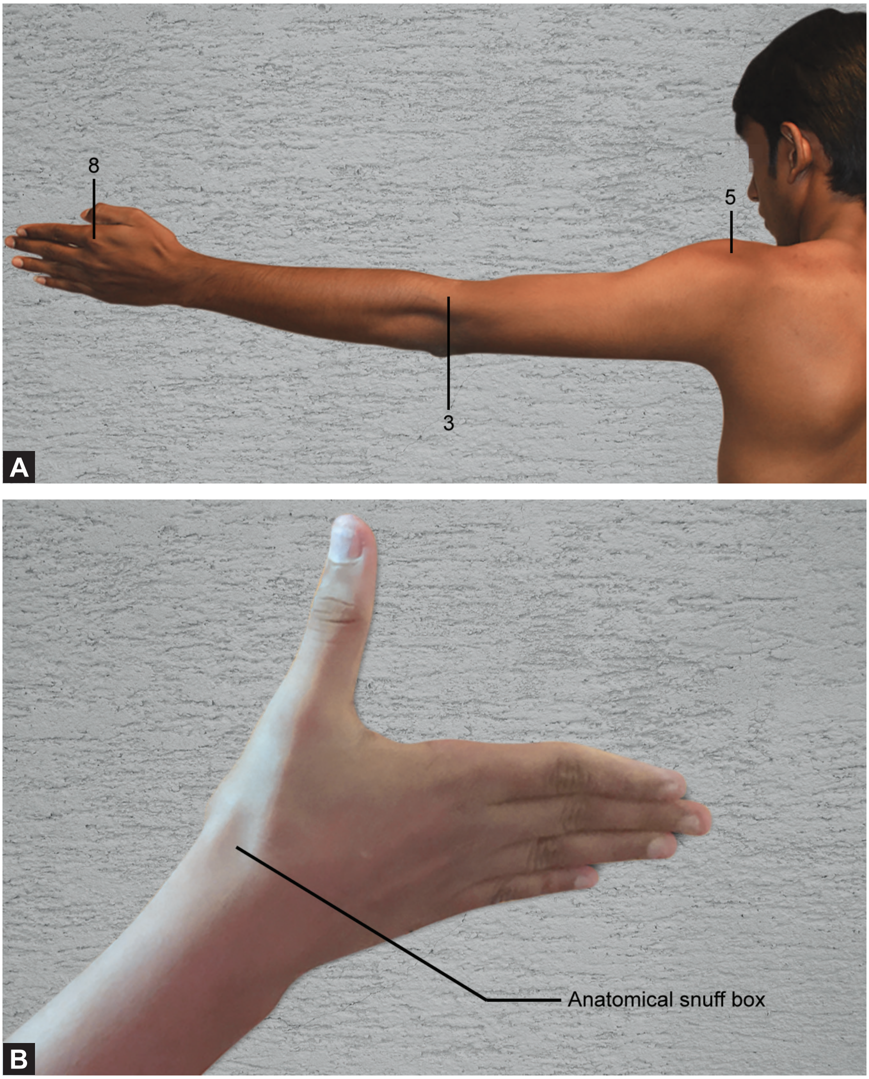
5

BONY LANDMARKS (FIGS. 5.1, 5.2, AND 5.4)

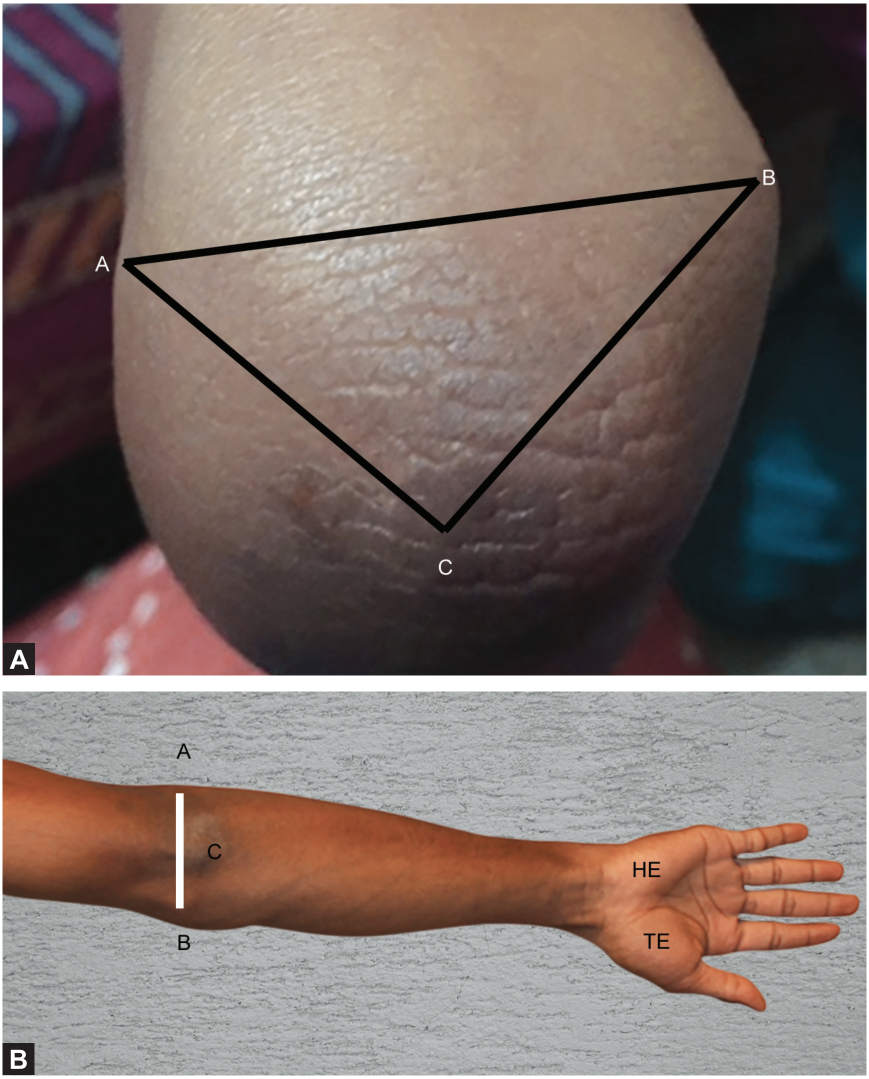
1. Clavicle
2. Acromion process
3. Lateral epicondyle
4. Medial epicondyle
5. Head of humerus
6. Styloid process of radius in supinated position.
7. Head of ulna in pronated position.
8. *Knuckles*: They are pointed projections seen on the dorsum of the hand when a fist is made. They represent the head of the metacarpal bones.
9. Medial epicondyle (A), lateral epicondyle (B) and olecranon process (C) of ulna form the angles of isosceles triangle in flexed elbow. The same bony landmarks lie in a single plane in extended position (Figs. 5.3A and 5.3B).
10. Axilla is also called the arm pit. It lies in the depression where the upper limb joins the trunk via the shoulder joint. It is bounded anteriorly by the anterior axillary fold formed by pectoralis major. The posterior axillary fold is formed by latissimus dorsi (Fig. 5.4).

Fig. 5.1: Upper limb bony landmarks.

11. The anatomical stuff box can be identified by extending the thumb when a depression can be seen (Fig. 5.2B).
    ***Anatomical snuff box*:** It is a triangular depression (bounded by extensor tendons of Pollex) seen on the lateral aspect of the base of the thumb. It becomes prominent in thin individuals on extension of thumb.
12. ***Thenar eminence*:** due to thenar muscles
13. ***Hypothenar eminence*:** due to hypothenar muscles.



Figs. 5.2A and B: (A) Upper limb: Back. (B) Anatomical snuff box.



Figs. 5.3A and B: (A) Medial (A), lateral epicondyle (B) and olecranon (C) process in a flexed elbow; (B) Olecranon process (C) medial (B) and lateral epicondyle (A) in an extended elbow. (HE: Hypothenar eminence; TE: Thenar eminence).

BLOOD VESSELS (FIG. 5.5)

Axillary Artery

It extends from the outer border of the 1st rib to the anterior axillary fold.

It is marked by:

a. Midpoint of the clavicle (A).

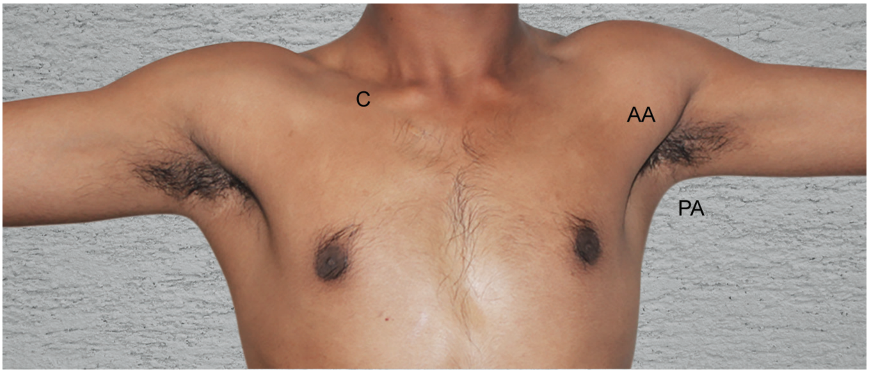


Fig. 5.4: Axillary folds. (AA: Anterior axillary fold; PA: Posterior axillary fold; C: Clavicle).

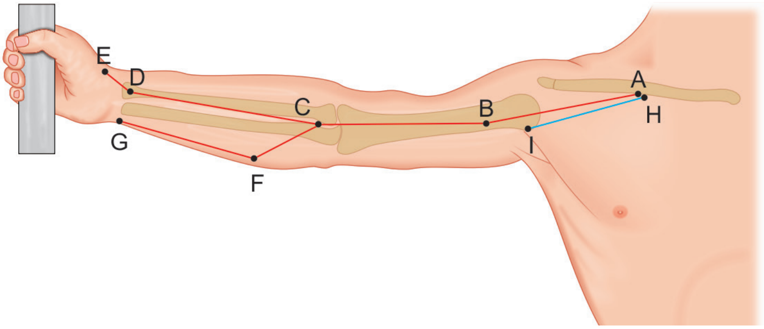


Fig. 5.5: Axillary, brachial, radial, ulnar artery and axillary vein. (AB: Axillary artery; BC: Brachial artery; CDE: Radial artery: CFG: Ulnar artery; HI: Axillary vein).

b. Lower limit of the lateral wall of the axilla between the axillary folds (B). Here the pulsation of the artery can be felt.
   The axillary vein is drawn just like the axillary artery but medial to it (HI).

Brachial Artery (Fig. 5.5)

It is the continuation of the axillary artery.

It extends from:

a. Lower limit of the lateral wall of the axilla midway between the anterior and the posterior axillary fold (B).
b. Neck of the radius, medial to the insertion of the tendon of biceps (C).
c. The tendon of biceps can be identified by flexing the elbow and making the tendon taut.

Applied Anatomy

The brachial artery palpation is important and regular clinical practice as this is the most common artery used for measurement of blood pressure. The pulsation of the brachial artery can be felt just medial to the tendon of biceps. The biceps can be made prominent by flexing the elbow.

Radial Artery (Fig. 5.5)

It is the smaller branch of the brachial artery.

a. It begins at the neck of the radius, medial to the tendon of the biceps (C).
b. A point on the anterior border of the lower end of the radius at the wrist (D).
c. The pulsations can be felt here.
d. Another point in the anatomical snuff box (E). The anatomical stuff box can be identified by extending the thumb when a depression can be seen.
e. Join the points C, D, and E.

Applied Anatomy

The radial artery is routinely palpated for pulsations and calculation of pulse. The radial artery is felt against the styloid process of the radius as the artery is superficial in this area and the pulsations can be felt clearly.

The radial artery is also used to draw arterial blood for blood gas analysis. The radial artery can also be used for cannulation during angiography.

Ulnar Artery (Fig. 5.5)

This is the larger branch of the brachial artery. It has a deeper course and becomes superficial at the wrist.

It is marked by:

a. Point at the neck of the radius medial to the tendon of the biceps (C).
b. Point at the junction of the upper one third and the lower two thirds of the medial border of the forearm (F).
c. A point lateral to the pisiform bone near the wrist (G).
d. Join points C, F and G.
e. It continues to form the superficial palmar arch.

Applied Anatomy

The ulnar artery is palpated for pulsations when we need to ascertain blood supply to the hand especially in conditions like peripheral vascular diseases, arteritis, etc. where any blood vessel may be affected.

Superficial Palmar Arch (Fig. 5.6)

It is the continuation of the superficial branch of the ulnar artery.

It is marked by:

a. A point lateral to the pisiform bone (A).
b. A point on the hook of the hamate (B).
c. A point on the distal border of the thenar eminence. A line through this point passes through the cleft between the index and the middle finger (C).
d. Join the points A, B and C with convexity distally toward fingers.

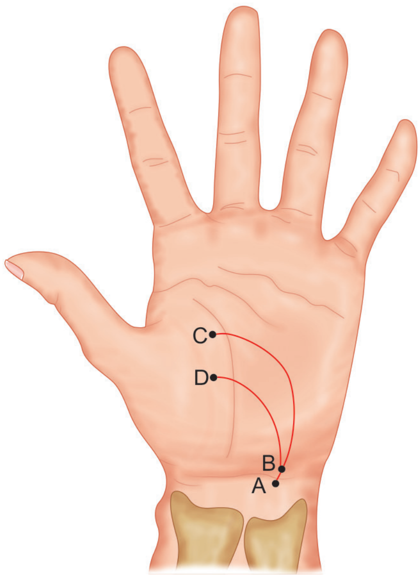


Fig. 5.6: Superficial and deep palmar arch. (ABC: Superficial palmar arch; BD: Deep palmar arch).

Deep Palmar Arch (Fig. 5.6)

It is the continuation of the radial artery. It has a deeper course.

a. A point on the hook of the hamate (B).
b. The arch is marked as a horizontal line at the hook of the hamate. It lies 1.2 cm proximal to the superficial palmar arch (D).

NERVES OF THE UPPER LIMB

Axillary Nerve (Fig. 5.7)

It lies deep to the deltoid muscle and closely related to the surgical neck of the humerus.

a. A point is marked at the tip of the acromion process (A).
b. Another point at the insertion of the deltoid muscle (B).
c. Join the points A and B.
d. Mid point of the line A and B, (D).
e. 2 cm above point D, (E).
f. A horizontal line of 3 cm along the point E.
g. This represents the axillary nerve.

Applied Anatomy

The axillary nerve is likely to get damaged in the upper posterior part of the arm over the shoulder. Hence care has to be taken while giving the injections to the deltoid. Ideally intramuscular injections are given in the upper lateral part of the arm to avoid injury to the axillary nerve.

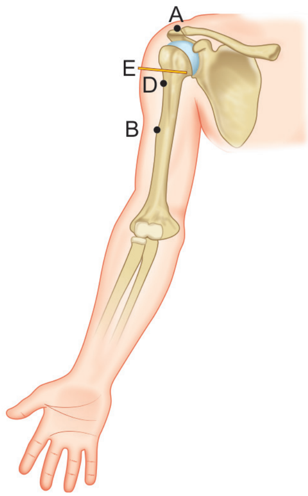


Fig. 5.7: Axillary nerve.

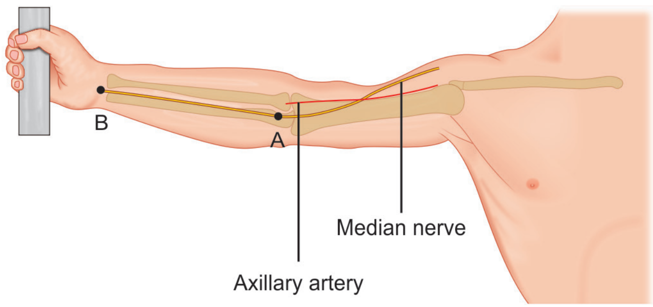


Fig. 5.8: Median nerve.

Median Nerve (Fig. 5.8)

***In the arm*:**

This nerve is closely related to the brachial artery.

a. Mark the brachial artery as in Figure 5.5.
b. In the upper half of the arm, mark a line lateral to the brachial artery.
c. In the lower half of the arm, continue the line medial to the brachial artery.
d. Thus the nerve crosses the artery in the middle of the arm.

Applied Anatomy

The median nerve lies very superficial in the wrist. It lies beneath the flexor retinaculum and might get easily damaged in injuries of the wrist. This may result in paralysis of the thenar muscles and lateral two lumbricals.

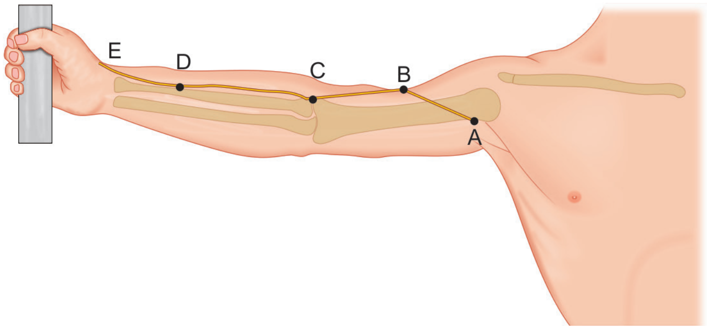


Fig. 5.9: Radial nerve.

***In the forearm*:**

a. Mark a point medial to the brachial artery at neck of the radius (A).
b. Another point at the middle of the palmar aspect of wrist (B).
c. Join A and B.

Radial Nerve (Fig. 5.9)

***In the arm*:**

a. A point in the lateral wall of the axilla at its lower boundary (A).
b. A point at the junction of the upper one third and lower two third of the arm along the lateral border (B).
c. A point at the level of the lateral epicondyle and lateral to the tendon of biceps (C).
d. Join points A, B and C. This is the radial nerve in the arm.

***In the forearm*:**

d. From the point C, mark a point at the junction of the upper two thirds and the lower third of the forearm along the lateral border of the forearm (D).
e. Another point at the anatomical snuff box (E).
f. Join points C, D, and E. This is the radial nerve lying lateral to the radial artery.

Applied Anatomy

The radial nerve is likely to be injured in the back of the arm (spiral grove) during improper administration of injection to the triceps brachii or deltoid.

The radial nerve also can be compressed temporarily in the middle posterior aspect of the arm (Saturday night palsy).

Ulnar Nerve (Fig. 5.10)

***In the arm*:**

a. Lower limit of the lateral wall of the axilla midway between the anterior and the posterior axillary fold (A).

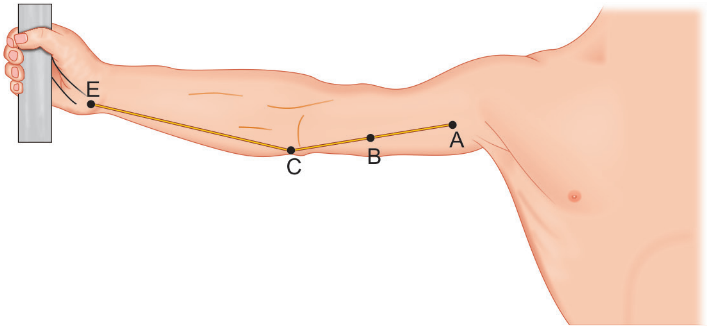


Fig. 5.10: Ulnar nerve.

b. Anterior aspect of the middle of the arm, medial to the brachial artery (B).
c. Behind the medial epicondyle (C).
d. Join A, B, and C.

***In the forearm*:**

a. Point behind the medial epicondyle (C).
b. Point lateral to the pisiform bone (E).
c. Join C and E. This is the ulnar nerve in the forearm.

Applied Anatomy

The ulnar nerve lies very close to the skin behind the medial epicondyle of the humerus and can be easily felt against the bone. Rolling the nerve against the bone causes twitching of muscles or a funny sensation on the medial aspect of the forearm, ring and little fingers.

The nerve may be crushed in the supracondylar fractures of the humerus involving the medial epicondyle.

The nerve also thickens in infectious diseases like leprosy (tubercular type). Palpation of this thickening helps in clinical diagnosis.

Flexor Retinaculum (Fig. 5.11)

Is a thick fibrous band in front of the wrist. It is attached to the carpal bones. Medially it is attached to the pisiform and hook of the hamate. Laterally it is attached the scaphoid and trapezium. The distal margin can be drawn at the level of where the thenar and hypothenar eminence meet.

Applied Anatomy

Flexor retinaculum with the carpal bones forms an osseoaponeurotic tunnel called carpal tunnel. The tunnel helps to hold the long flexor tendons in place for their optimal

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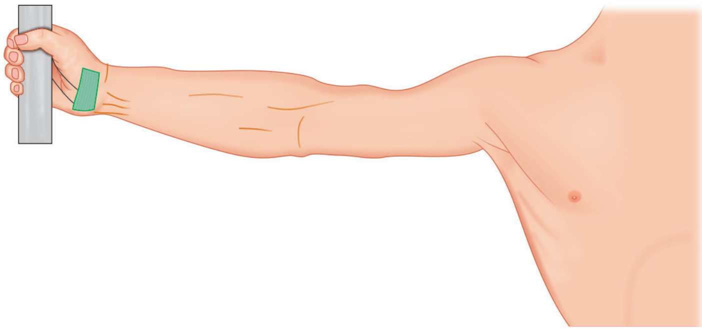

Fig. 5.11: Flexor retinaculum.

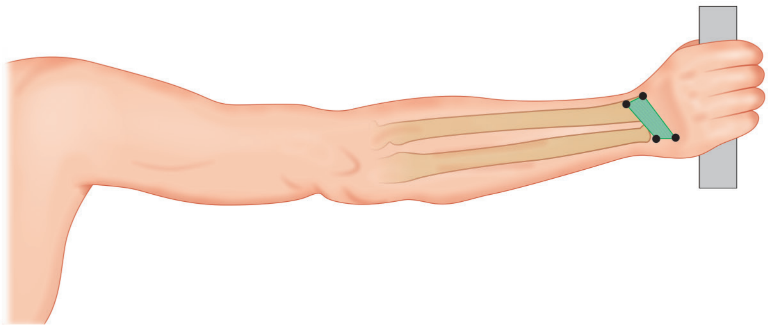

Fig. 5.12: Exensor retinaculum.

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functionality. The tunnel might get tightened causing compression of the median nerve, deep carpal veins and carpal artery in sequence.

The compression of the median nerves leads to carpal tunnel syndrome.

Extensor Retinaculum (Fig. 5.12)

Mark the anterior border of the radius just above the styloid process. Mark the pisiform and triquetral bone. The band is around 1.5 cm thick. The band is higher on the lateral side than the medial side.

Applied Anatomy

The extensor retinaculum needs to be accessed when trying to surgically release the pressure of the inflamed synovial sheaths in Dequervains tenosynovitis.

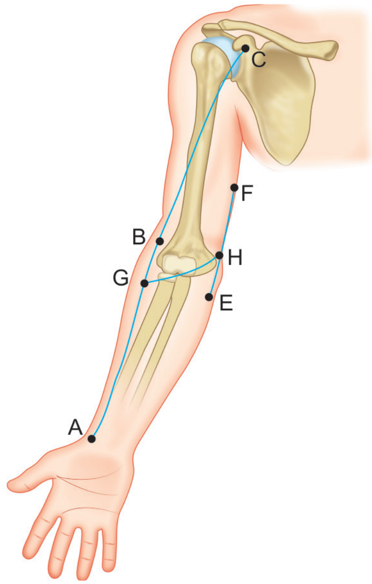


Fig. 5.13: Cephalic, basilic and median cubital vein. (ABC: Cephalic vein; EF: Basilic vein; GH: Median cubital vein).

Cephalic Vein (Fig. 5.13)

a. Point in the anatomical snuff box (A).
b. Point on the lateral side of the elbow (B).
c. Point at the middle of the deltopectoral groove (C).
d. Join A, B, and C.

Applied Anatomy

The superficial veins are used to draw blood for investigations or give drugs by intravenous route. This allows immediate and fast action of the drugs as they are injected directly into the general circulation.

Functional position of the hand is described as 15° flexion of the wrist, 90° flexion at the metacarpophalangeal joints and extension of the interphalangeal joints. This position puts the ligaments at full length and relaxes the muscles. This facilitates healing in the right position and providing optimum functional utility post-trauma/surgery.

***Basilic vein*:** Drawn by joining the following points (Fig. 5.13).
e. Anterior surface of forearm below the medial part of the elbow (E).
f. Point on the medial side of the arm midway between medial epicondyle and axilla (F).

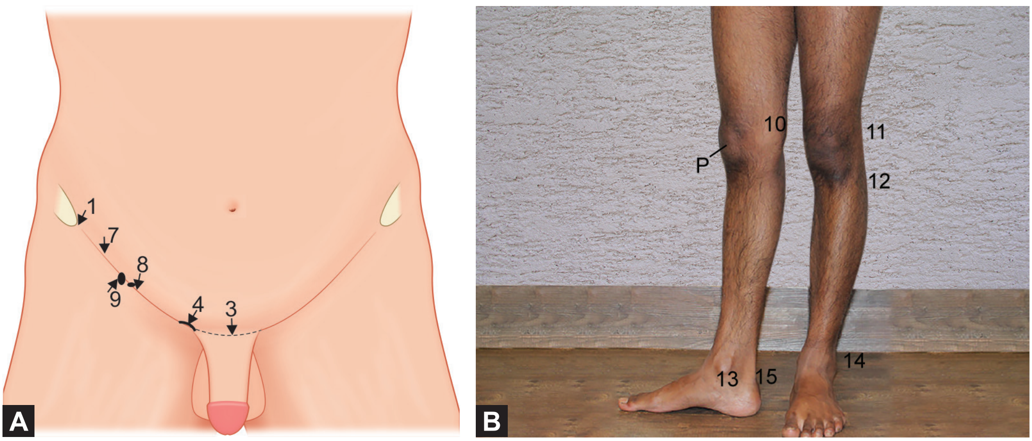
***Median cubital vein*:** (Fig. 5.13)
g. A point 2 cm below the lateral side of the elbow (G).
h. A point 1.5 cm above the medial epicondyle (H).
i. Join G to H.

Surface Anatomy of the Lower Limb

6

BONY LAND MARKS (FIGS. 6.1A AND B)

1. ***Anterior superior iliac spine*:** is felt as a tubercle at the lateral end of the groin as the lateral attachment of the inguinal ligament.
2. ***Anterior inferior iliac spine*:** This lies as a tubercle about 3 cm below the anterior superior iliac spine.
3. ***Pubic symphysis*:** Central point of the pubis.
4. ***Pubic tubercle*:** From the midline, this is palpated as a tubercle 2 cm lateral to the pubic symphysis.
5. ***Tubercle of the iliac crest*:** This is felt as a tubercle about 5 cm behind the anterior superior iliac spine along the iliac crest.
6. ***Greater trochanter (GT)*:** This is palpated about 7.5 to 8 cm below the tubercle of the iliac crest.
7. ***Inguinal ligament*:** This is felt in the fold of the groin at the junction of the abdomen and the anterior aspect of thigh.
8. ***Midinguinal point*:** Mark a point midway between the anterior superior iliac spine and the pubic symphysis.
9. ***Midpoint of the inguinal ligament*:** Mark a point midway between the pubic tubercle and the anterior superior iliac spine.
10. ***Adductor tubercle*:** A tubercle 5 cm above the medial epicondyle of the femur.



Figs. 6.1A and B: Bony landmarks of lower limb.

11. ***Lateral Epicondyle of Femur***
12. ***Tibial tuberosity*:** This is felt as a tuberosity on the tibia. Feel the patella and continue the palpation downwards to feel the tibial tuberosity.
13. ***Medial malleolus of Tibia*:** is most prominent bony land mark on the medial aspect of the ankle.
14. ***Lateral malleolus of Fibula*:** is most prominent bony landmark on the lateral aspect of the ankle.
15. ***Tendocalcaneous*:** This a tough fibrous tendon seen in the lower aspect of leg posteriorly above the heel.

***Nelaton's line (Fig. 6.2A)*:** An imaginary line extending from the anterior superior iliac spine to tuberosity of ischium of the pelvis. This is in supine position. The tip of the greater trochanter normally lies at the level or below this line. If the greater trochanter lies above the line, this indicates hip dislocation or hip fracture.

***Bryant's triangle (Fig. 6.2B)*:** This is marked in supine position.

a. Draw a line from the anterior superior iliac spine to the greater trochanter.
b. Draw a line from the anterior superior iliac spine vertically downwards.
c. Draw a line from the GT perpendicular to the previous line (C).

16. ***Saphenofemoral junction (Fig. 6.3)*:** The pubic tubercle. Mark a point 4 cms below and lateral to the pubic tubercle. Draw an oval opening around the point.

Applied Anatomy

The saphenofemoral junction is identified to block the opening of the saphenous vein and prevent retrograde flow during clinical examination of varicose veins.

The bryants triangle has to be drawn on both sides. This helps to find out supratrochanteric shortening of hip by comparison of both sides. The most common causes for supratrochanteric shortening of the hip is in dislocation of hip, fracture neck of femur, coxa vera.

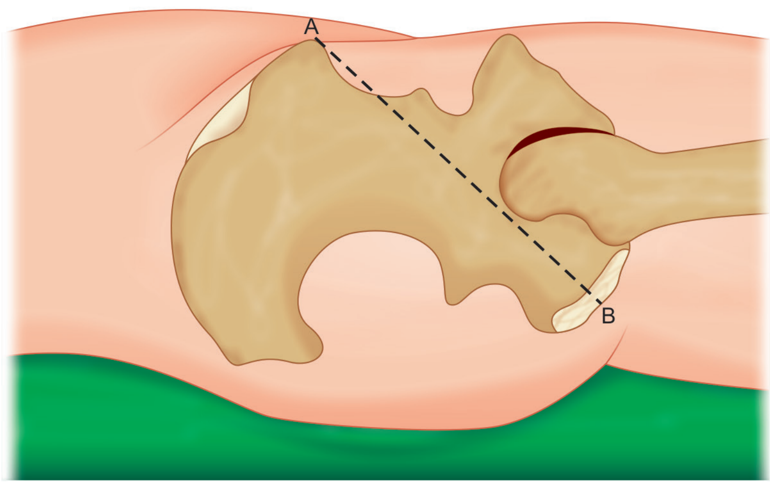


Fig. 6.2A: Nelaton's line. (A: Anterior superior iliac spine; B: Ischial tuberosity).

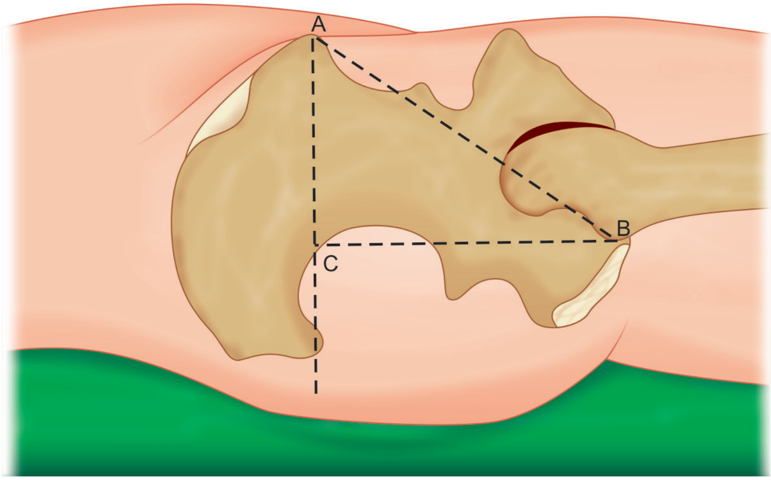


Fig. 6.2B: Bryant's trianle. (A: Anterior superior iliac spine; B: Greater trochanter).

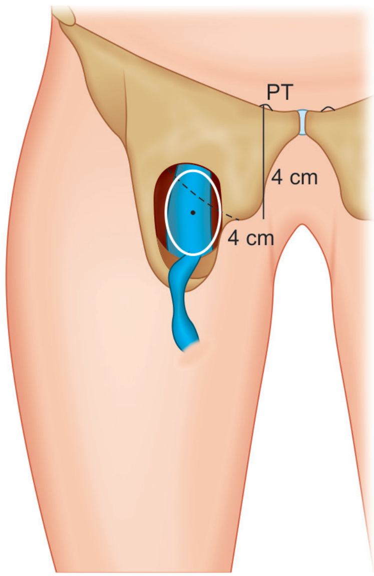


Fig. 6.3: Saphenofemoral junction. (PT: Pubic tubercle).

Femoral Artery (Fig. 6.4)

a. Mark the midinguinal point (A).
b. Mark the adductor tubercle (D). The adductor tubercle is located about 5 cms above the medial epicondyle.

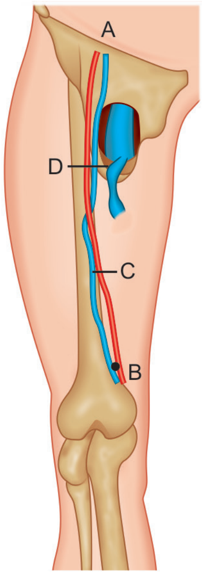


Fig. 6.4: Femoral artery and vein. (AD: Femoral artery in femoral triangle; DC: Femoral artery in adductor canal).

c. Join the two points by a line. Divide this line into three equal parts. The upper one third represents the femoral artery (AD) in the femoral triangle and middle third represents the femoral artery in the adductor canal (DC).
   Thus, the upper two-thirds of this line represents the femoral artery (AC).

Applied Anatomy

The femoral artery is palpated just below the midinguinal point. The position of the lower limb should be extension at hip, lateral rotation of the thigh and semiflexion at knee. Once the femoral is palpated for, it is used to introduce the catheter for various purposes, the most common being the coronary angiography.

The femoral artery can be used to draw arterial blood when radial artery cannot be used.

***Femoral vein (Fig. 6.4)*:** Mark the femoral artery. In the upper half draw a line medial to the artery and in the lower half continue the line lateral to the artery.

Applied Anatomy

The femoral vein can be used to draw blood especially in patients in shock where distal veins may have collapsed or already cannulated and also it can be cannualted for Hemodialysis.

And also when a large vessel needs to be cannulated for injecting radiographic dyes, inotropic drugs(drugs to increase blood pressure in patients in shock).

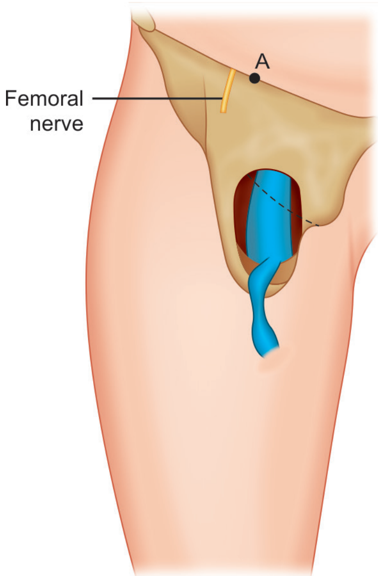


Fig. 6.5: Femoral nerve.

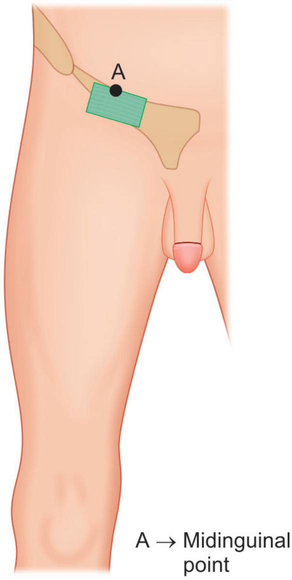


Fig. 6.6: Femoral sheath.

Femoral nerve (Fig. 6.5)

a. Mark the midinguinal point.
b. Draw a line of 2.5 cm length 2 cm lateral to the midinguinal point.
c. This represents the femoral nerve.

Femoral sheath (Fig. 6.6)

a. Mark the midinguinal point.
b. Draw a rectangle below the point.
c. The rectangle is 2.5 cm long and 3 cm broad.

Inferior gluteal artery (Fig. 6.7)

a. Mark the posterior superior iliac spine (A) and the ischial tuberosity (B).
b. Join the two points.
c. Mark the midpoint of this line (C).
d. Draw a line downwards about 2.5 cm lateral to the midpoint.

Superior gluteal artery (Fig. 6.8)

a. Mark the posterior superior iliac spine (A) and the greater trochanter (B).
b. Join the two points.
c. Draw a line upwards from the junction of lateral 2/3rd and medial 1/3rd (C).
d. This indicates the stem of the superior gluteal artery.

Sciatic nerve (Fig. 6.9)

a. Mark the posterior superior iliac spine (A) and the ischial tuberosity (B). Join the points.
b. Mark a point lateral to the midpoint of this line (C).
c. Mark the greater trochanter (D). Join the greater trochanter to the ischial tuberosity.

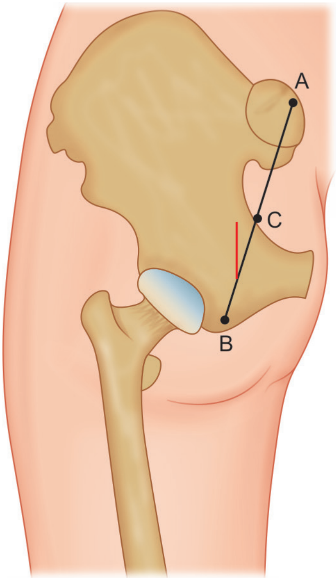


Fig. 6.7: Inferior gluteal artery.

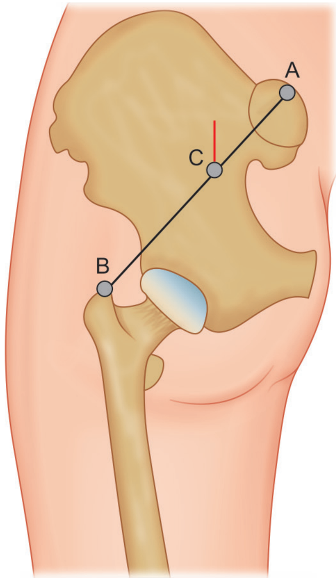


Fig. 6.8: Superior gluteal artery.

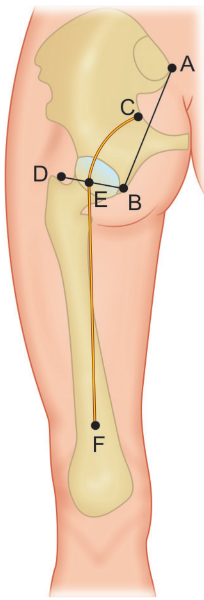


Fig. 6.9: Sciatic nerve. (CEF: Sciatic nerve).

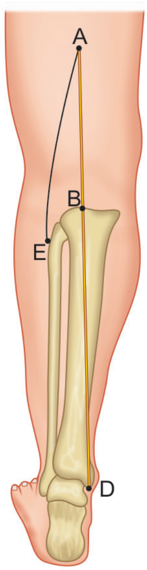


Fig. 6.10: Tibial and common peroneal nerves. (ABD: Tibial nerve; AE: Common peroneal nerve).

d. Mark the midpoint of this line (E).
e. Mark the apex of the popliteal fossa in the thigh (F).
f. Join all the three points. This marks the sciatic nerve (CEF).

Applied Anatomy

Iatrogenic injuries of the sciatic nerve can be prevented by giving intramuscular injections into the upper and outer quadrant of the gluteal region.

Tibial nerve (Fig. 6.10)

a. Mark the upper limit of the popliteal fossa (A), lower limit of the popliteal fossa (B) and the point midway between medial malleolus and tendocalcaneus (D).
b. Join the points to mark the tibial nerve.

Common peroneal nerve (Fig. 6.10)

a. Mark the upper limit of the popliteal fossa (A).
b. Mark the neck of the fibula (E).
c. Join the points to mark the common peroneal nerve.

Applied Anatomy

The common peroneal can be palpated through the skin at the neck of the fibula. This nerve also thickens when infected with leprosy and a valid point for clinical diagnosis. The neck of the fibula is vulnerable to fractures and invariably the common peroneal nerve gets injured leading to foot drop.

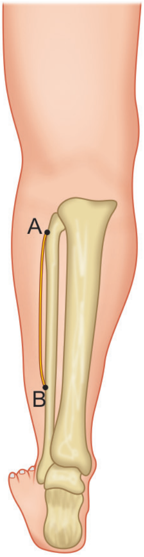


Fig. 6.11: Superficial peroneal nerve.

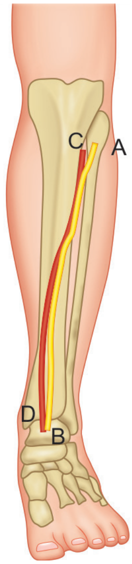


Fig. 6.12: Deep peroneal nerve and anterior tibial artery. (AB: Deep peroneal nerve; CD: Anterior tibial artery).

Superficial peroneal nerve (Fig. 6.11)

a. Mark the neck of the f2ibula (A).
b. Mark a point at the junction of the middle 1/3rd and lower 1/3rd of the peroneus longus muscle (B).
c. Join the two points.

Deep peroneal nerve (Fig. 6.12)

a. Mark the neck of the fibula (A).
b. Mark a point midway between the malleoli (B).
c. Join the two points. The nerve lies lateral to the anterior tibial artery in the upper and lower thirds of its course and over the artery in the middle third.

Anterior tibial artery (Fig. 6.12)

a. Mark a point 2.5 cms medial to the neck of the fibula (C).
b. Mark the point midway between the two malleoli (D).
c. Join the two points.

Popliteal artery (Fig. 6.13)

a. Mark a point at the junction of middle and lower third of the back of thigh (A).
b. Mark a point at the level of tibial tuberosity on the back of the leg (B).
c. Join the two points.
d. This will mark the popliteal artery.

Applied Anatomy

The popliteal artery is the artery used for measuring the blood pressure of the lower limb. The stethoscope diaphragm is kept in the popliteal fossa for auscultation of the popliteal artery.

The lower limb pressure measurement is significant for diagnosis of co-arctation of aorta.

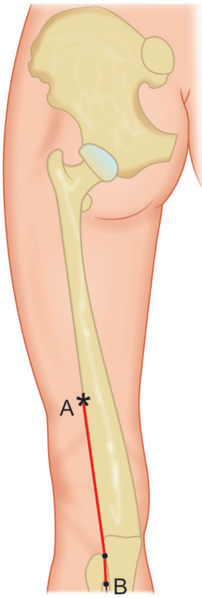


Fig. 6.13: Popliteal artery.

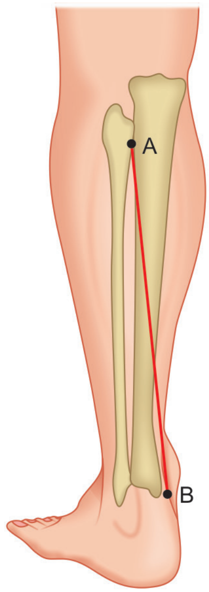


Fig. 6.14: Posterior tibial artery

Posterior tibial artery (Fig. 6.14)

a. Mark the point at the midline of the leg at the level of the neck of the fibula (A).
b. Mark a point midway between the medial malleolus and the tendocalcaneus (B).
c. Join the two points.

Dorsalis pedis artery (Fig. 6.15)

a. This is the continuation of the anterior tibial artery.
b. Mark a point midway between the malleoli (A).
c. Mark a point at the base of the 1st inter metatarsal space just lateral to the tendon of extensor halucis longus (B).

Applied Anatomy

The peripheral artery pulsations of anterior tibial, posterior tibial and dorsalis pedis is regularly felt during clinical examination of lower limb. Their presence indicates clear blood flow through the respective blood vessels. This is of diagnostic importance in peripheral arterial disease called thromboangitis obliterans.

Medial Plantar nerve and artery (Fig. 6.16)

a. Mark a point midway between the medial malleolus and prominence of the heel (A).
b. Mark a point at the first intermetatarsal cleft on the sole at the level of navicular bone (B).
c. Join A and B.
d. The medial plantar nerve is lateral and the artery is medial.

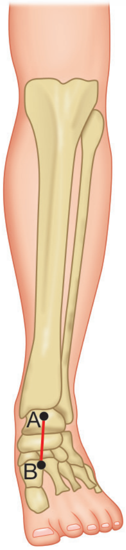


Fig. 6.15: Dorsalis pedis artery.

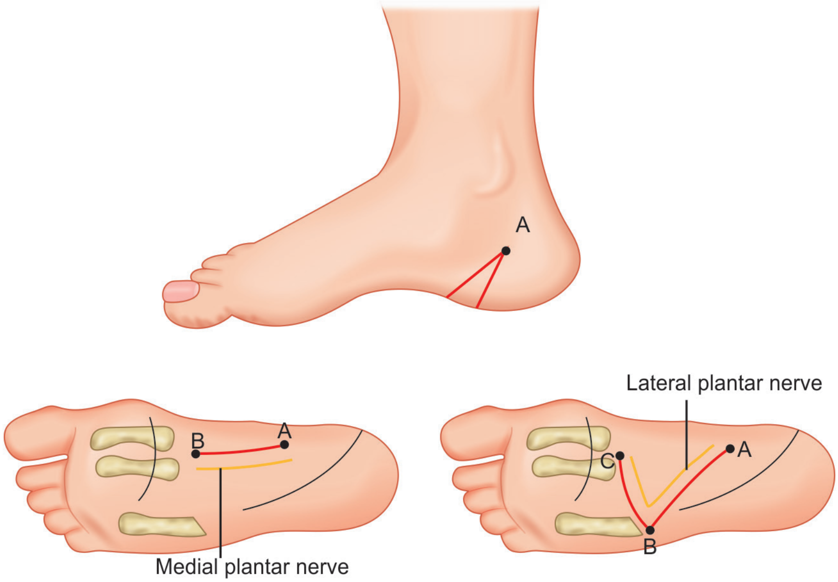


Fig. 6.16: Medial and lateral plantar vessels and nerves. (AB: Medial plantar artery; ABC: Lateral plantar artery).

Lateral plantar nerve and artery (Fig. 6.16)

a. Mark a point midway between the medial malleolus and prominence of the heel (A).
b. Mark a point at the tubercle of the 5th metatarsal bone (B).
c. Proximal part of the first intermetatarsal space (C).

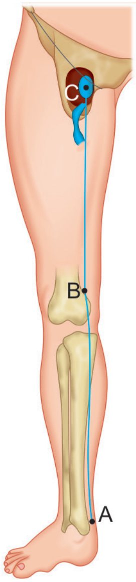


Fig. 6.17: Great saphenous vein.

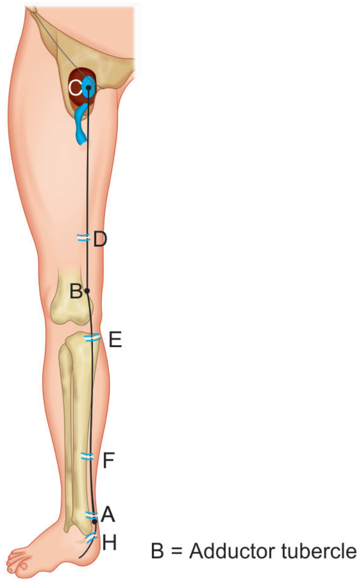


Fig. 6.18: Perforators of the leg.

d. Join A, B and C.
e. The lateral plantar artery is lateral and the nerve is medial.

Great saphenous vein (Fig. 6.17)

a. Mark a point just behind the medial maleolus (A).
b. Mark a point at the adductor tubercle (B).
c. Mark a point at the saphenofemoral junction (C).
d. Join the points to form the great saphenous vein.

Applied Anatomy

Great saphenous veins is the most common vein to get varicosed. Hence surface anatomy of the great saphenous and location of its perforators is important to identify and differentiate the level of varicosity.

Location of perforators (Fig. 6.18)

There are mainly 5 perforators of the great saphenous vein.

The perforators veins are veins which connect the superficial veins with the deep veins. Hence they help in the venous drainage from superficial to deep veins. They have valves which are located at the junction of the veins it connects. They allow unidirectional flow of venous blood from superficial set of veins to deep veins only.

a. *Perforator in the adductor canal*: Located about 5 cms above the adductor tubercle (D).
b. *Perforator below the knee*: Located below the knee joint on the medial aspect (E).
c. *Upper Perforator of the leg*: Located at the junction of lower and middle thirds of the leg (F).

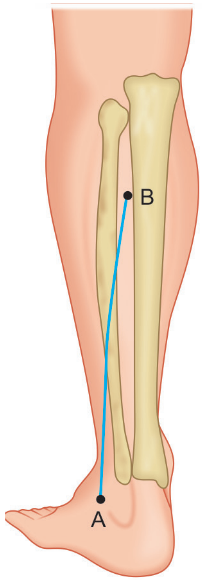


Fig. 6.19: Short saphenous vein.

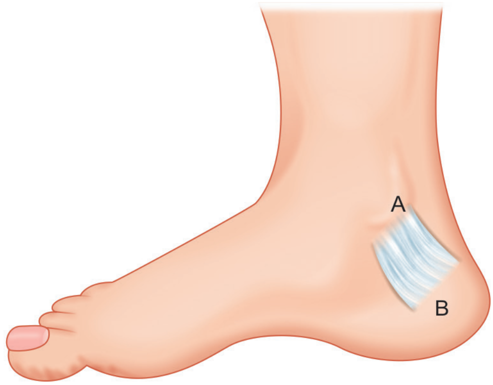


Fig. 6.20: Flexor retinaculum.

d. *Middle perforator of the leg*: Located just above the medial malleolus (G).
e. *Lower perforator of the leg*: Located postero-medial to the medial malleolus (H).

Applied Anatomy

The location of perforators are very important as this helps in clinical examination when the level of valve defect and extent of varicose veins needs to be detected.

Many tests are performed to locate defects in the perforators by using the surface anatomy of location of these perforators.

Short saphenous vein (Fig. 6.19)

a. Mark a point below the lateral malleolus (A).
b. Mark a point at the junction of the middle and the upper third of the leg in the midline (B).
c. The line joining and B represents the short saphenous vein.

***Flexor retinaculum (Fig. 6.20)*:** Draw a band of 2 cm width between the medial malleolus (A) and the tubercle of the calcaneum (B).

***Superior extensor retinaculum (Fig. 6.21)*:** Draw a band of 3 cm width between the anterior borders of the lower aspect of the tibia and the fibula.

***Inferior extensor retinaculum (Fig. 6.21)*:** Mark the stem at the lateral tubercle of the calcaneum. The upper band is drawn up to the medial malleolus. The lower band is drawn medially to the plantar aspect of the foot.

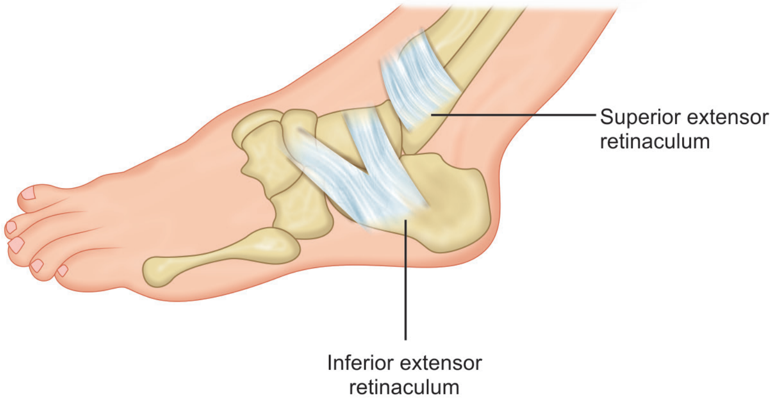


Fig. 6.21: Superior and inferior extensor retinacula.

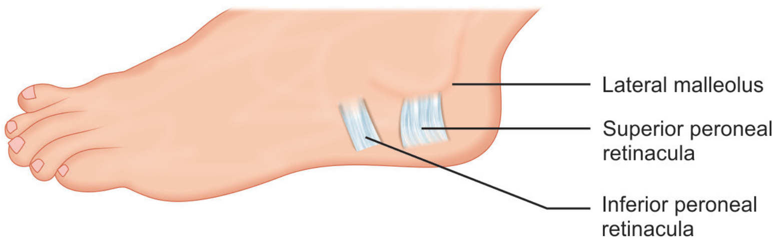


Fig. 6.22: Peroneal retinacula.

***Superior peroneal retinaculum (Fig. 6.22)*:** A band of 2 cm width is drawn from the lateral malleolus to the lateral tubercle of calcaneum.

***Inferior peroneal retinaculum (Fig. 6.22)*:** A band of 2 cm width is drawn from the lateral tubercle of the calcaneum to the superior surface of the calcaneum. This becomes continuous with the stem of inferior extensor retinaculum.

Section 2

Radiological Anatomy

CHAPTERS

7

Introduction

Diseased is subjected to three stages of investigations to diagnose and treat:

1. *History*: Disease is diagnosed by taking the history of onset of disease and its manifestations in the form of symptoms from the patient.
2. The diagnosis of the disease can be short listed by the clinical examinations.
3. Investigations are carried out to pin point the disease which helps for specific treatment.

In the investigations, the body fluids like blood, urine, secretions of glands, hormones, cerebrospinal fluid, ECG (EKG: electrocardiogram), EEG (electroencephalogram), lung function tests, etc. are examined. Then the patient is subjected to Imaging of the affected part of the body which has become a very essential part of diagnosis nowadays.

The imaging techniques are of two types:

Ionizing

i. Conventional radiography (conventional X-ray)
ii. Fluoroscopy
iii. Tomography
iv. Computed tomography
v. Radioisotopes

Nonionizing

i. Ultrasound
ii. Magnetic resonance imaging (MRI) or Nuclear magnetic resonance (NMR)
iii. DSA/DVA (Digital subtraction angiography or Digital vascular angiography)
iv. PET (Positron emission tomography)
v. PACS (Picture achieving and communication systems).

8

Radiology Principle

DEFINITION

It is a branch of medical science that deals with the use of radiant energy in the diagnosis and treatment of disease.

This radiant energy, called X-ray, was discovered by Wilhelm Conrad Roentgen in 1895.

X-rays are a form of energy waves compared to visible light rays, but they are shorter in length and travel in straight line. These rays can penetrate through the tissues of the body and also are partially absorbed by the tissues. Some X-rays which pass through the body without being absorbed. All the above can be recorded on X-ray film in varying densities.

The X-rays are produced in a glass tube which has vacuum and contains a wire filament at one end and a target of tungsten wire at the other end. The filament releases electrons when heated by an electric current to become luminous (white heat). These electrons are made to accelerate toward the target by applying a very high voltage between the filament and the target. The high velocity electrons lose their kinetic energy after striking the target and release X-rays as a form of energy. The X-ray tube made of glass, has to be covered by lead tube except a small hole for the passage of X-rays (Fig. 8.1).

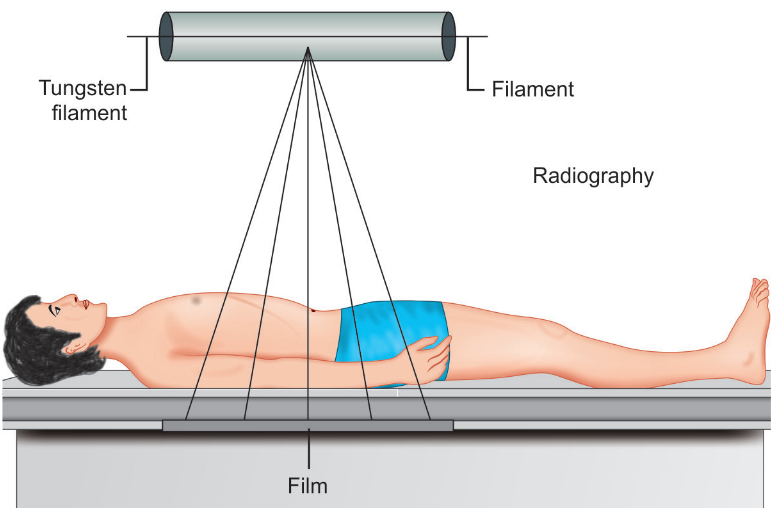


Fig. 8.1: The principles of radiography.

Fig. 8.2: Radiography machine.

The tube is placed on one side of the body and the X-ray film is kept on the other side of the body depending upon the organ to be examined. The X-rays pass through the body—some are absorbed completely, some partially, and some do not get absorbed at all which come out to react with the chemical applied on the X-ray film (Figs. 8.1 and 8.2).

RADIOGRAPHY

High density tissues like bones absorb the X-rays and the low density tissues either partially absorb or transmit the X-rays without any absorption. Thus, the absorption is less for soft tissue, water or fluid; further reduced in case of fat and least absorption in case of air-filled organs like lungs. When the film is exposed to the rays passing through the body, the part of the film behind the bony structures receives very minimal rays because most of the rays would have been absorbed by the bones leading to underexposure to the rays. Therefore the rays do not reach the X-ray film and react with the chemical applied to the film. Hence the field with maximum absorption will appear radiopaque. This is called "**radiopacity.**"

When the rays pass through the air-filled organs they reach the film and react with the chemical, (the film) causing black shadow when the film is washed. Such areas are called "**radiolucent**" or "**radiotranslucent**." X-rays passing through the soft tissue cause grey shadows as the rays are partially absorbed (Figs. 8.3 and 8.4).

Calcium salts, water, soft tissues, fat and air have got density differences to be distinguishable from each other by varying in the grey scale on a conventional radiographic examination.

Fig. 8.3: The epiphysis, epiphyseal disk, and diaphysis.

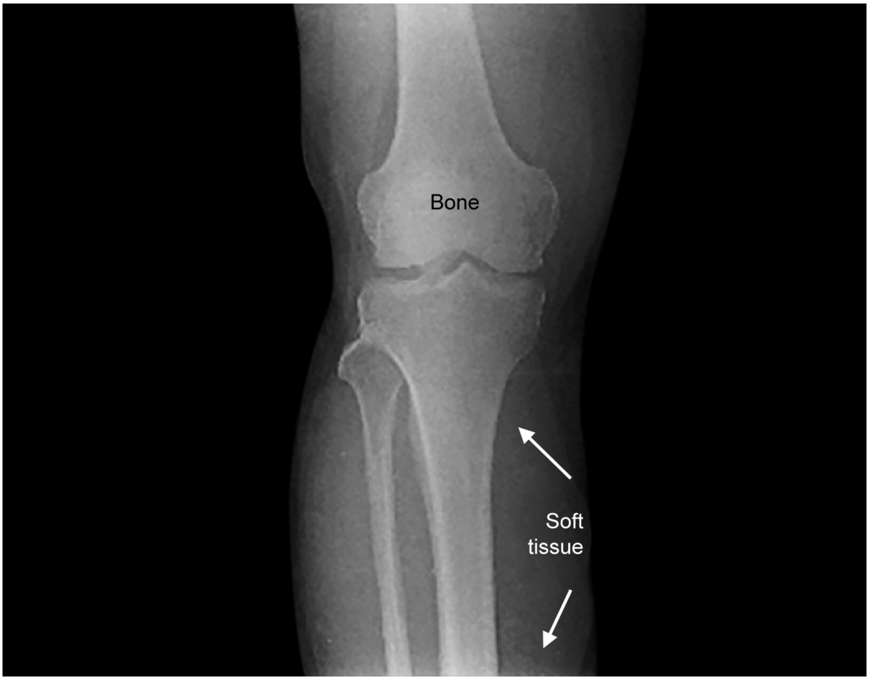


Fig. 8.4: Shows difference between bony (radiopaque) and soft tissue shadows (radiotranslucent).

Properties of X-rays

1. ***Penetration*:** Substances of lower atomic weight transmit the rays, whereas those with higher atomic weight absorb the X-rays. Such property has been used to identify the shadows of the organs or the part depending upon the grey scale from black to white (radiolucent and radiopaque, respectively). Calcium-rich tissues like bone cast a white shadow. The soft tissues (like muscles, fascia, vessels, nerves, tendons ligaments, etc.) absorb X-rays partially to give an image of varying gray scale. Substances like fat and air do not absorb any X-rays and give a totally black shadow.
2. ***Photographic property*:** The X-rays affect the chemical (bromium salt) which is applied as an emulsion on the X-ray film. During the development of the films, after they are exposed to the X-rays, the radiolucent parts appear dark (black) due to the reaction between light and the bromium salt. Radiopaque parts appear white as there is no reaction between emulsion and light and the emulsion is washed out without any or much reaction.

   The film which is developed after the exposure to X-rays by passing through the body is called SKIAGRAM (skia = shadow, gramma = writing) or RADIOGRAM and the procedure done to obtain the radiogram is called RADIOGRAPHY.
3. ***Fluorescence property*:** Light waves are produced when X-rays strike certain metallic salts like phosphorous salts. This is called fluorescence and this forms the basis of "screening" in fluoroscopy.
4. ***Biological properties*:** X-rays can destroy abnormal cells like tumor cells, without destroying the normal cells to some degree. This is the basis for radiotherapy. But X-rays can injure the normal living cells and cause death of the cells when exposed for a longer period and in high dosage. The damage can be an intractable necrosis, especially of the skin, leukemia, gonadal cell damage, etc. In fetus, exposure to a small dose of the X-rays also will lead to leukemia. In gonadal damage, abnormal spermatocytes can be formed leading to malformations in offspring.

Hence personnel involved in radiology and radiotherapy department have badges which measure the radiation exposure. Once the limits are crossed the personnel are posted out of the department.

RADIOGRAPHIC VIEWS

The radiographs can be taken from various aspects called views.
These are:

1. Anteroposterior view
2. Posteroanterior view
3. Lateral view
4. Oblique view.

These terminologies indicate the direction in which the X-rays pass.

*In **anteroposterior view***: The X-rays pass from anterior to the posterior aspect of the body. In this the X-ray tube is placed on the anterior aspect of the body and the film is kept on the posterior part of the body. Thus, the rays pass from anteroposteriorly.

In ***posteroanterior view*****:** The rays pass from posterior to the anterior side of the body (posteroanteriorly). X-ray tube is on the posterior aspect of the body and the film is on the anterior part of the body.

Lateral views can be right lateral or left lateral and the X-ray tube and the X-ray film are kept accordingly.

Oblique views are other than the above mentioned views.

The purpose of this arrangement is that the organ or the part of the body which is to be examined should be as near as possible to the X-ray film to get a sharper or a clear shadow.

- In thorax, the heart is more anteriorly placed and in order to get a sharp well-defined shadow of the heart posteroanterior view is used. In abdomen, the kidneys, lumbar vertebre, and colon are more posteriorly placed therefore the film is behind and the X-ray tube is in front. Hence, the view is anteroposterior. The orientation of the radiograph is done by placing the lead letters, "L" or "R" on the cover containing the film indicating the left and right side of the body respectively.

Radiographic Appearances of Various Tissues of the Body

Structures with density difference like air, water, fat, or bone can be easily differentiated.

Bones**:** Due to the presence of high calcium content, the bones are clearly defined and contrasted with soft parts.

Homogenous white shadow in a long bone is the compact part of the bone and deeper, less dense, greyish part is the medullary cavity. Between the compact part and the medullary cavity there are irregular white lines which represent lamellae indicating the spongy or cancellous bone. In case of long bones the spongy part cannot be differentiated. In case of skull bones the spongy bone, called diploe, is in the middle and it is bounded by inner and outer thick white parts made up of compact bone called inner and outer tables. In long bones the lamellae in the spongy bone are arranged along the direction of stress but these are joined by cross connecting lamellae. Such ones are seen in **calcaneum (largest tarsal bone)** and **neck of the femur (called calcar femorale)**.

In case of immature bones, at full term and just before birth, many bones are made up of cartilages. The cartilage has the same kind of radio density as that of muscles and other soft tissue. Therefore, cartilage shadows are not seen in plain radiograms.

Sometimes the parts of the body are far away from the X-ray film giving rise to enlarged and hazy shadows. This can be overcome by increasing the tube—film distance. For an effective image, the body is placed at a distance of 6 ft (2 m) from the X-ray tube and the film is around 30 cm from the body.

The **secondary centers**, in case of growing bones, can be visualized in the radiograms which are called "**epiphyseal centers**." The part of the bone between the epiphyseal center and the diaphysis is the cartilage and is called the epiphyseal or diaphyseal disk which appears as a narrow transradient band in the radiograph. The part of the diaphysis lying adjacent to the epiphyseal disk appears as an opaque line represents the **metaphysis**. The metaphyseal line is seen only at the growing end of the bone (*see* Fig. 8.3).

Many of the ***soft tissues*** are not visible on plain radiographs except those which are dense and highly vascular, like kidneys, intestines due to the presence of gas or if there is calcification of any structure in the body.

Therefore, to visualize the bones and calcified or air-filled structures a plain radiography is sufficient (*see* Fig. 8.4).

CONTRAST RADIOGRAPHY (FIG. 8.5)

In order to visualize other soft parts, like the hollow organs, a contrast medium needs to be introduced into cavities (***contrast radiography***). The contrast can also be used to visualize the vascular system where it is called as an **angiogram**.

The following are the contrast radiographs done to visualize various organs and organ systems.

For ***alimentary canal*****:** Barium swallow for esophagus, Barium meal for stomach, Barium meal follow through for small intestine, and Barium enema for large intestine.

Salivary ducts**:** Sialography

Extra hepatic biliary apparatus**:** Cholecystography

Tracheobronchial tree**:** Bronchography

Urinary system**:** Descending and ascending pyelography

Female reproductive system**:** Hysterosalpingography

Subarachnoid space around spinal cord**:** Myelography

Ventricles of the brain**:** Ventriculography

Vessels**:** Angiography (Arteriography, Venography, Lymphangiography)

Angiogram consists of arteriogram, venogram, and lymphangiogram.

The contrast medium**:** A substance injected into the organ of interest for visualization. The commonly used contrast medium are:

1. Air
2. Barium sulfate
3. Sodium iodide

The contrast media used should be either of low density like air or high density like barium or iodine preparations (Fig. 8.5).

The **contrast medium** selected should have the following properties:

1. Easily available.
2. Nontoxic to the body.
3. Easily introducible into the part or the body.
4. Should be sufficiently radiopaque or radiolucent: The high density contrast substances are radiopaque and cause white shadows like bone or more intense than bone shadow (barium swallow). The low intensity substance like air produce radiolucent which appear as black shadows (ventriculogram).

Fig. 8.5: Visualization of the rectum by contrast radiography (Barium enema).

5. Should not be absorbed into the tissues.
6. Should be excreted easily from the body.
7. Cost effective.

***Double contrast radiography*:** It is used to visualize the shapes of various structures like alimentary canal. In this a barium sulfate solution is given for the coating of the mucosa and air is filled into the lumen. In such a method, barium sulfate produces a fine, white coating which stands out very clearly against air filled lumen. Hence the name double contrast radiography.

This is contraindicated if there is perforation or any obstruction in alimentary canal. In such conditions Iodine containing water soluble contrast medium is used to get the contrast.

FLUOROSCOPY

X-rays are not perceived by the human eyes. But the rays have got the property of causing certain substances to fluoresce, i.e. make the structure to emit light of a longer wave length, which is visible to the eyes. Therefore, fluorescence of a thin layer of zinc sulfide or barium platinocyanide, placed on a card board screen in front of the object to be visualized. The X-rays pass through the object, reacts with the chemicals on the film. This reaction makes X-ray image of an irradiated object visible.

Advantages

It is performed

1. To observe the movement of diaphragm, ribs, and pulmonary vessels.
2. To see the changes in the transradiancy of the lung fields during respiration.
3. To see the shape and movements of the heart.
4. To see the changes in the level of intestine during respiration or when there is change in the position of the body (standing or lying down).
5. The mobility and intrinsic motility of the part of the alimentary canal (peristalsis).
6. Pulsations of the left ventricle can be assessed in cases of suspected aortic aneurysm.
7. Assessment of positioning of the body part during radiological and surgical procedures.
8. Different views of the organ may be quickly and easily seen on slow rotation of the subject which helps in locating the obliquely placed parts of alimentary canal.
9. The activity of the various parts of alimentary tract can be observed during the passage of barium sulfate when combined with barium swallow, barium meal, or barium enema procedures.

MAMMOGRAPHY (FIG. 8.6)

This is one of the procedures used to visualize the internal structure of the breast. This is used as screening and diagnostic tool. This procedure is done to detect the early stages of breast cancer. In this procedure a very low energy X-rays are used to examine the mammary

Fig. 8.6: Mammography machine.

glands (about 30 kV). The cancerous growths appear as micro calcifications in the X-ray shadows.

***Procedure*:** The breast is compressed using parallel plate compression for examining uniform thick breast tissue which facilitates proper penetration of the tissue by the X-rays with less scattering. On the day of examination the women are advised not to apply talcum powder, lotions, or deodorants as these may mislead by showing up in the radiographs.

There are two types of mammograms:

1. ***Screening mammogram*:** Performed yearly even in absence of symptoms and consist of four standard images of X-ray. It is done in women with family history of breast cancer.
2. ***Diagnostic mammogram*:** It is done in patients with symptoms or if there is any abnormality in the breast shadow during screening procedures. This procedure is done in case of breast implants and breast reductions.

The results of mammograms are expressed in terms of **BI-RADS** score. The categories vary from 0 to 6 (0 = incomplete and 6 = malignancy).

Disadvantages

- False negative pictures that are obtained due to dense tissue which obscure the cancerous growths due to overlapping. This may require repeated mammography.
- It may be controversial in case of normal individuals when they do not present any symptoms.
- If repeated exposure is done due to repeated screening it may lead to after effects of long term X-ray exposure.
- Some of the cancers like lobular breast cancer presents with shadows of mammary glands which are indistinguishable from normal.
- There may be false positive reports which may cause panic in patients.
- Higher spatial resolution is required.
- It is expensive.

POSITRON EMISSION MAMMOGRAPHY (PEM)

It is a procedure which is used to detect breast cancer. It is an adjunct to the conventional mammography. In this procedure a pair of gamma radiation is used which are placed above and below the breast and a mild compression is applied to the breast to detect the gamma rays after the administration of a radioactive sugar molecule, a radio nucleotide called "**fluorine -18 fluorodeoxyglucose" (18F – FDG)**. This procedure is similar to Positron Emission Tomography (PET) studies used for the whole body examination of any metastatic disease. This procedure helps in detecting the lesions which are as small as 2 mm. The radio active nucleotide is injected into the blood stream and a scanner is used to detect the areas of high Fluoro D Glucose (FDG) uptake as the cancer cells require high energy for their growth than the normal cells. The scanner generates images which show hot spots in high uptake areas. This procedure helps in staging the cancer, planning for surgery, and treatment evaluation.

Arteriogram

Visualization of arteries by radiographic method after introducing a radiopaque substance (contrast material) into that artery is called arteriography and the image obtained is the arteriogram. This procedure helps in observing the blood flow and also blocks if any.

Types of Arteriograms

Depending upon the arteries of the organ or the region the method is named. For example, to visualize aorta, it is called **aortogram**, to visualize arteries of the brain, it is **cerebral angiogram**, to visualize the arteries of the neck, the procedure is **carotid angiogram**, to see the arteries o the heart, it is **coronary angiography, pulmonary angiography** for the vessels of the lungs, to see the blood vessels of the limbs it is called extremities angiography, for kidney vessels it is **renal angiography**, to visualize the retina, choroid (parts of the eye) it is called **fluorescent angiography**.

Before doing the procedure the patient is enquired about the allergy to medicines, list of medicines taken especially blood thinners and pregnancy in case of female during fertility period. Allergy to iodine has to be tested as it is used in the procedure as a contrast material.

During the procedure, a mild sedative is given. The artery to be examined is injected with the help of the catheter introduced and radiographs are taken in required position. Arterial wall damage or the narrowing of the lumen, hemorrhage, aneurysms, inflammatory conditions, thrombosis and tumors, if present, are observed in the procedure and through the same catheter treatment also can be given which minimizes the invasive procedure by avoiding repetition of the procedure.

***The disadvantages*:** Allergic reaction to the contrast medium used, pain at the site of introduction of the catheter, bleeding or sometimes blood clot formation at the site of introduction of catheter, low blood pressure or stroke followed by coronary angiography which may lead to heart attack in very rare cases.

After the procedure is over the catheter is to be removed and pressure is applied to the insertion site. Posture is also important in stopping the bleeding.

ULTRASOUND (FIGS. 8.7 AND 8.8)

Ultrasound is a form of energy, which occurs in waves similar to sound waves. Audible sound waves are of 20 to 20,000 cycles (dB) per second. The sound waves which are greater than 20,000 dB per second are not audible by human beings and are called "**ultrasound waves**." The soft tissues can be penetrated by ultrasound waves which are partially reflected at tissue interphases.

The ultrasound waves are sent by a probe called as **ultrasound transducer**. These sound waves reflect as echoes from the parts of the tissues. The echoes are received by the transducer. Depending on the density of the tissue the reflections of the waves/echoes are produced are recorded and displayed as an image. These images are called **sonogram**. Ultrasonography can be used to view two/three dimensional images, blood flow dynamics and tissue movement of a region.

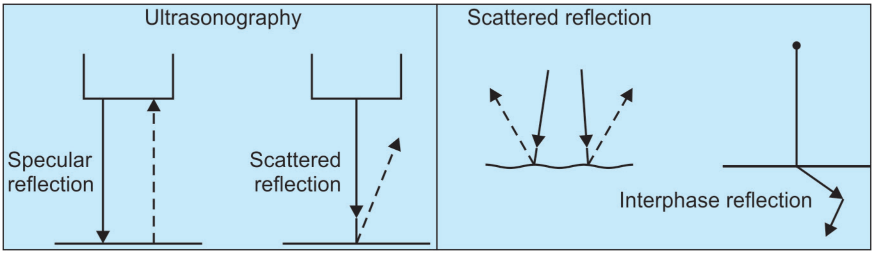


Fig. 8.7: Principles of ultrasonography.

Fig. 8.8: Ultrasonography machine.

Lower frequencies have longer wavelengths and can penetrate into deeper structures. But their resolution is less. Higher frequency sound waves have a smaller wavelength and are capable of reflecting or scattering from smaller structures (high resolution). These waves limit the depth of penetration of the sound wave into the body. Diagnostic scanners operate in the frequency range of **2–18 MHz**, though frequencies up to 50–100 MHz have been used in biomicroscopy in case of examination of anterior chamber of the eye.

The transducers can be **surface transducers** and **internal transducers**. The surface transducers move over the surface of the body. The internal transducers are used intravaginal, endorectal, or transesophageal to visualize the internal architecture of the structures.

Ultrasound waves have also been used for **therapeutics** such as breakdown of gallstones, renal stones, phacoemulsification in cataract, to stimulate the bone growth, in cleaning the teeth, to break the blood brain barrier to facilitate the passage of drug treatments. It has also been used to destroy the cancerous or diseased tissue.

Ultrasound gels are used between the transducer and the region being examined. This forms a tight bond between the two and acts as a conductive medium for complete transmission of the waves. Any air between the transducer and the skin will not allow complete transmission as ultrasound will not travel well in air.

Advantages

1. Low cost
2. Image in real time or live image.
3. Equipment/instrument is small and can be carried to patient's bedside if the patient is unable to move.
4. The equipment is flexible.
5. No harmful radiation to damage the tissues. It has no short-term or long-term side effects and does not cause any kind of discomfort to the patient.
6. Superficial structures like mammary gland, thyroid, parathyroid glands, brain in case of neonates, muscles, tendons, testes, are imaged at a higher frequency (7–18 MHz) which provides better lateral and axial resolution.
7. Delineating the interfaces between solids and fluid filled spaces is better in these images.
8. It is a very safe method even in pregnancy to examine the fetus. It helps in calculating the gestational age, to know the viability of the embryo/fetus, location of fetus, number of fetuses, position of placenta and its relation to cervix, physical abnormalities of fetus, movements and heart beat in fetus, and sex of the fetus.

Disadvantages

1. It has limitations in case of examining tissues which are behind the bones, bones being denser. Do not allow the waves to reach the organ behind it. So it requires skill of the operator who can turn the instrument to get a proper image for retro skeletal tissues.
2. The performance is very poor when there is gas between the transducer and the organ to be examined. For example, examination of pancreas becomes difficult when there is gas in the gastrointestinal organs.
3. The depth of penetration of the waves is also limited and may not penetrate the deeper organs irrespective of the bones being absent; which may be due fat in obese patients.
4. Prediction/interpretation of the image can only be done by experts.

Newer Imaging Techniques

9

TOMOGRAPHY (FIGS. 9.1 AND 9.2)

It is a procedure in which images are produced on an X-ray film of a selected thin section of a specific region of the body. The parts in front and behind are made inconspicuous. Such a slice which is being imaged is usually few millimetres thick. In this procedure, the X-ray tube and the film are moved in contrary directions.

Thus the distance CD–point X will cast single shadow throughout the exposure but opacities at the other level such as Y' will cast continuous shadow, so that their image is blurred and merges with general blackening of the radiograph. By moving the tube and film for a distance of E and F, the point Y will produce single shadow, throughout the exposure and the image of X is blurred. Continuous exposure is made during which the tube is moved from A to B and film from C to D. In modern tomography equipment, circular, elliptical and various other movements can be made and thus different layers can be examined

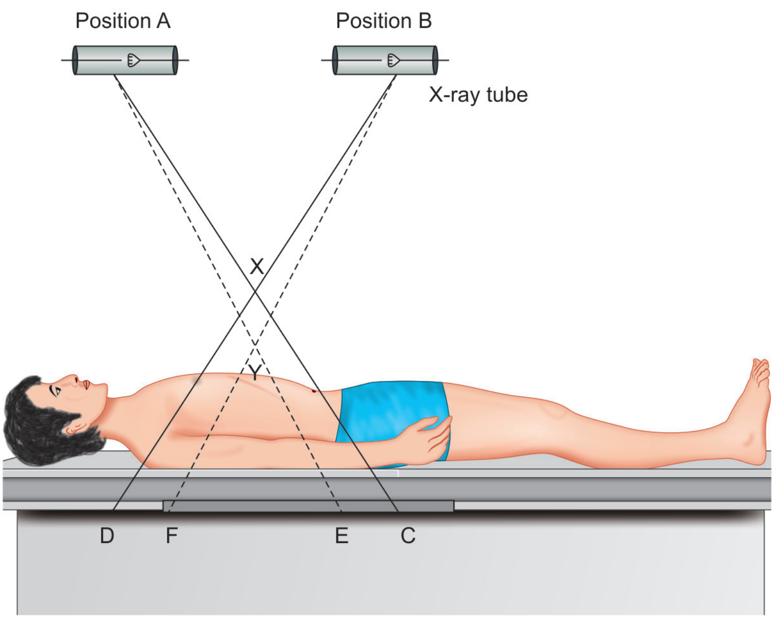


Fig. 9.1: Principles of tomography.

Fig. 9.2: Computed tomography (CT) machine.

and unwanted shadows of layers can be eliminated. Like radiography, tomography shows shadows of structures with different density (Fig. 9.1).

Indications

Small lesions which are poorly/not visualized by plain radiographs due to superimposition of the shadows of various related structures.

COMPUTED TOMOGRAPHY (CT)/COMPUTER AXIAL TOMOGRAPHY (CAT) (FIGS. 9.2 AND 9.3)

It was developed in 1972 by Hounsfield.

Basically, CT scans consist of a highly sensitive X-ray beam that is focused on a specific plane of the body.

As this beam passes through the body, it is picked up by a detector, which feeds the information it receives into a computer. The computer then analyzes the information on the basis of tissue density. This analyzed data is then fed into a cathode ray tube (the device responsible for producing pictures on the TV screen), and a picture of the X-rayed, cross-section of the body is produced. **Bone shows up as white; gases and liquids as black; and other soft tissues as varying shades of gray, depending on its density.**

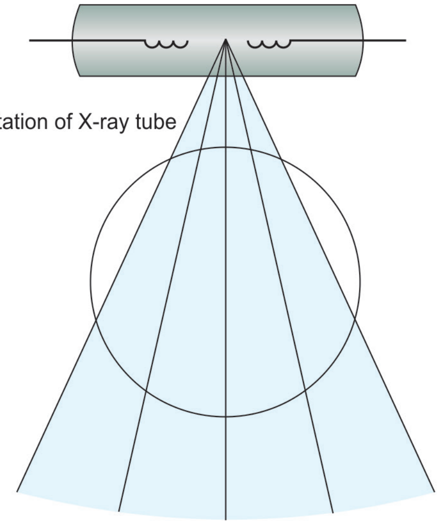


Fig. 9.3: Principles of computed tomography (CT).

The CT/CAT scan is a non-invasive diagnostic procedure. It is a combination of X-rays and sophisticated computers to produce section images of the body's interior. It helps in the discrimination between tissues of slight density difference like tumor in liver or brain which otherwise is not possible in plain radiographs.

PRINCIPLE

The X-ray tube and the detectors are mounted on a common stage/frame and are placed opposite to each other. A narrow beam of X-ray is directed at the region to be examined. This frame rotates around the region to be imaged and innumerable recordings of transmitted radiation are made. These recordings are sent to the computer which constructs a transverse sectioned image of examined region and displays on the monitor screen. This gives rise to series of images at various levels. Computer manipulations can be used to remove unwanted tissues shadows such as bone which are obstructing the details. The images thus formed can either be photographed or can be stored in the CD (compact disk). The radiation dose is same as that of conventional radiography.

Shadows are like those in the conventional radiographs—white or radiopaque areas indicating bones which are more dense areas and black or radiolucent in case of air filled spaces which are less dense areas (Fig. 9.4). Soft tissues are in various grey shades, depending upon the density of the soft parts which lie in that plane.

The patient should be asked to wear simple, loose fitting clothing. The metals like jewellery, dentures, pins, eye glasses will affect the CT, therefore should not be worn during the procedure.

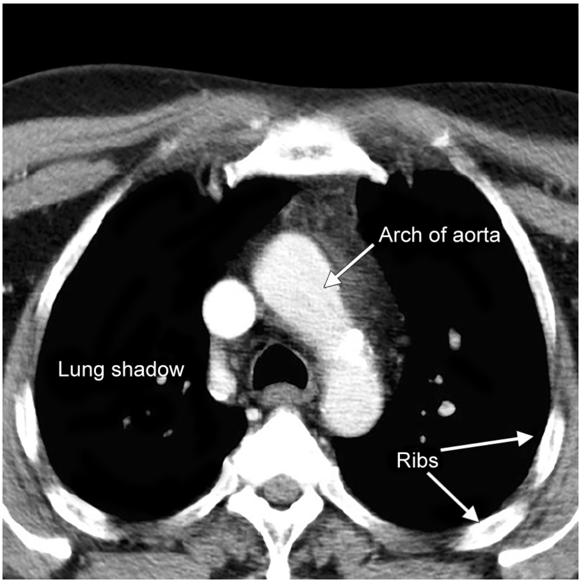


Fig. 9.4: Computed tomography (CT) of thorax showing different shades of gray from black to white indicating air in the lungs (black) and bone (white) shadows. Other soft tissues appear grey.

Indications

Computed tomography is used to identify the structures which are in the head and neck, thorax, abdomen, etc. is used to diagnose trauma, musculoskeletal disorders, infectious diseases, appendicitis, cardiovascular disease, cancers, etc. as it gives a detailed cross-sectional view. Assessment of vascularity of organs can also be made.

Contraindications

Pregnancy.

Contrast Computed Tomography (Fig. 9.5)

1. It is a procedure done to visualize the internal organs and structures around them. The contrast material used is radiopaque. Two types of contrast material used. They are:
   a. Oral contrast/Rectal contrast
   b. Intravenous contrast.
2. Both are used while performing CT scan of abdomen. The contrast material brighten the internal organs, tissues, vessels, etc. as it passes through them. It provides accuracy in diagnosis. It helps in the detection of subtle cancers and other diseases.
3. In oral contrast, barium sulfate is used just like in case of contrast radiography but with more dilution than in general radiography. It may be up to 2% concentration of barium

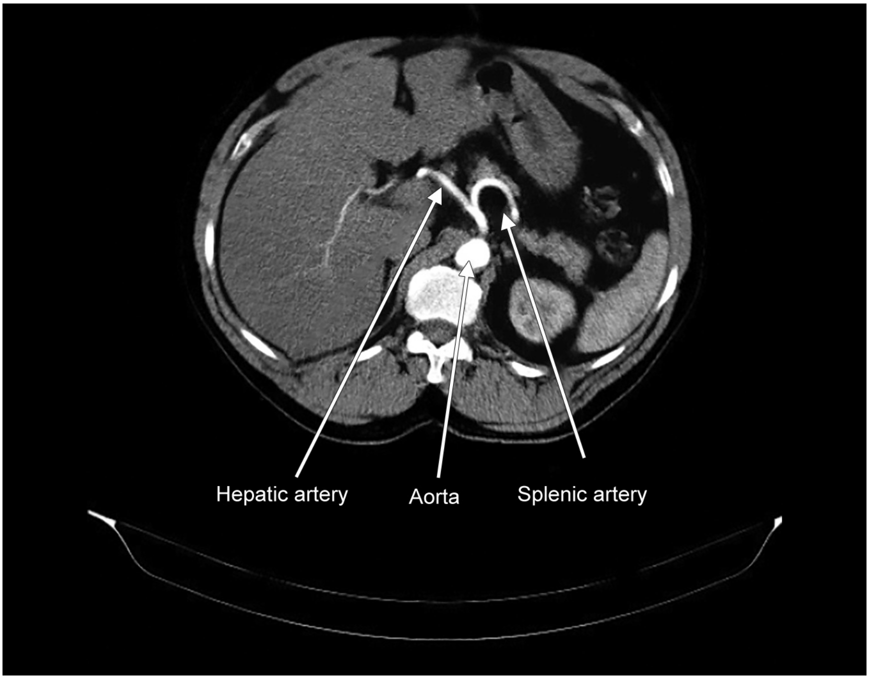


Fig. 9.5: Contrast computed tomography (CT) showing the contrast medium injected into the arteries which appear like bone shadows—white in color (contrast tomography arteriogram).

sulfate solution and patient is made to drink about 1000 mL to 1500 mL of the solution for stomach and small intestine.

4. For large intestine barium enema is given
5. The other material used as contrast media are—shellfish, iodine, Gastrograffin, Gasroview, etc.
6. The intravenous contrast material highlights the blood vessels and enhances the tissues like kidneys, liver, brain spinal cord etc. Contrast material is provided in the form of package in a sterile glass bottle or injection vial. About 75 to 150 cc of contrast material is injected using sterile syringe depending on the region to be examined, age and weight of the patient. The cardiovascular system should be evaluated before the procedure is performed.
7. A written consent is to be signed by the patient or patient's relative.
8. Fasting for 3 to 4 hours prior to the procedure may be recommended in some cases.
9. History of allergy should be noted.

MAGNETIC RESONANCE IMAGING (MRI) OR NUCLEAR MAGNETIC RESONANCE (NMR) (FIG. 9.6)

Atoms in the body can act as minute magnetic bars with North and South poles. When an external magnetic force is applied to the part of the body, each tiny magnet lines up with the

Fig. 9.6: Magnetic resonance imaging (MRI) machine.

magnetic field. An MRI machine (Fig. 9.6) uses computer-controlled radio waves and very big magnets, which create a magnetic field roughly 25,000 times stronger than the Earth's magnetic field. When the body is subjected to radio waves, some of the magnets absorb the radio waves. The protons get excited by the absorbed waves. The radio wave is then turned off and subsequently the magnets rebroadcast and the protons emit a radiofrequency signal. Such reflected signal can be picked up by an antenna and then sent to the computer which makes a picture or scan from the signal. The computer processes the data made by the magnetic field from the response of a proton which is measured. The proton involved in this process is hydrogen ion of the water present in the tissues of the body.

In MRI images, bones appear dark; bone marrow which is filled with fat appears white. Surrounding subcutaneous tissue appears white. Soft tissue appears grey or white depending on the procedure (Fig. 9.7).

Advantages

- MRI scans are devoid of any artifacts.
- As there is absence of signals from structures containing body fluids, like blood, which are rapidly flowing, give rise to a clearly demarcated parts. For example, blood vessels.
- The areas, like edema or hemorrhage, which are not visualized in CT scan, are accurately visualized by MRI.
- MRI is the investigation of choice in multiple sclerosis.
- No ionizing radiation
- Very high soft tissue resolution

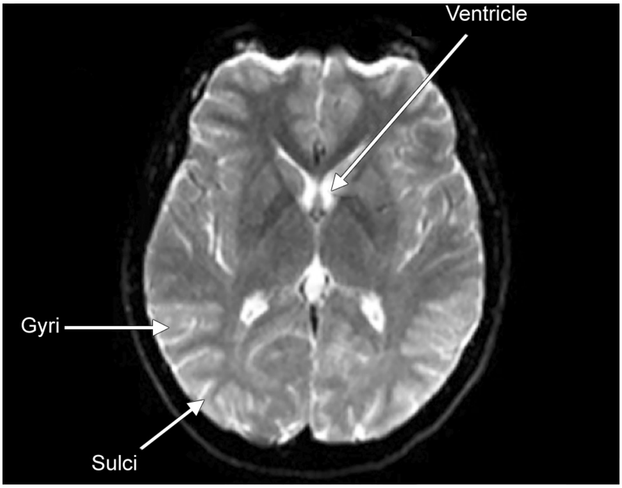


Fig. 9.7: Magnetic resonance imaging (MRI) of the head region showing ventricles containing cerebrospinal fluid as white shadows. The grey and white matters appear as shades of grey.

- Can image vessels without injection of intravascular contrasts.
- Direct transverse, sagittal and normal imaging is possible.
- No bone or air artifacts.

Disadvantages

- High cost
- Inability to image bone
- Unsuitable for patients with cardiac pace makers
- MRI has no known associated health risks. However, people with aneurysm clips, or other implants like cochlear implants that contain magnetic materials are generally advised not to undergo MRI testing. The strong magnetic fields can dislodge metal objects that are in the body. Even worse they can overload implanted electronic devices and render them useless. Always tell your physician and the technologist if you have implanted medical devices before you enter the magnet suite.

DIFFERENCES BETWEEN CT AND MRI

Computed tomography (CT) scans and MRIs are both diagnostic tests that provide us with high-resolution pictures of the structure of any organ or area of the body, which requires a thorough examination. Both tests take place in big, somewhat intimidating machines. They each use computers to construct pictures of the inside of the body. There are, however, inherent differences in these tests mechanisms, as well as sophistication and applications (Table 9.1).

Table 9.1: Shows the differences between CT and MRI.

	CT scan	*MRI*
Requirement	X-rays	Magnetic field
Time taken	30 seconds to 5 minutes	Minimum of 30 minutes
Cost	About half the price of MRI	Double the cost of CT scan
Radiation exposure	Present and not advised in pregnancy and young children	No radiation exposure effects are seen Can be used in pregnancy and young children
Scope of application	Bone shadows are seen very accurately, it is best suited for examining the chest, bones, lungs, and for cancer detection	Soft tissue shadows are very clearly seen Accurate in localizing the area of edema, hemorrhage, which are difficult to visualize through computed tomography
Limitations of the procedures	Patients with metal implants can get CT scan.	Patients with cardiac pacemakers, tattoos and metal implants are contraindicated due to possible injury to patient and dislodgement of the metallic devices or image distortion (artifact). Any ferromagnetic object may cause trauma or burn.
Contrast material used	Non-ionic iodinated agents covalently bind the iodine and have fewer side effects. Allergic reaction is rare but more common than MRI contrast. Risk of contrast induced nephropathy	Water is best contrast medium for GIT. Nano particles are being used now a days as contract substances. Very rare allergic reaction. Risk of nephrogenic systemic fibrosis with free gadolinium in the blood and severe renal failure. It is contraindicated in patients with GFR under 60 and especially under 30 mL/min.
Comfort aspect of the patient	Very rarely creates claustrophobia	Often creates claustrophobia in susceptible patients.

CONTRAST MRI

In this procedure, the contrast media are used to improve the visibility of internal structures of the body in MRI. The most commonly used compound is "gadolinium based". These agents shorten the relaxation time of atoms in the tissues of the body after intravenous administration or oral administration (for gastrointestinal system).

The MRI contrast media are classified depending upon magnetic properties, chemical composition, administration route, presence of metal atoms, nature of metal atoms, biodistribution and effect on the image.

The MRI contrast media consist of intravenous contrast agents, blood pool agents, organ specific agents (GIT), hepatobiliary organs, tumor specific agents, bioactivated agents and pH sensitive agents. There are newer agents identified which are protein based contrast material. This is based on the interactions and binding between amino acids and gadolinium.

Gadolinium is used intravenously to study blood vessels specifically as in magnetic resonance angiography (MRA). It is used in brain tumor enhancement associated with degradation of blood brain barrier. For aorta and its branches the concentration of the contrast medium can be 0.1 mmol per kg body weight. Higher concentrations are used for

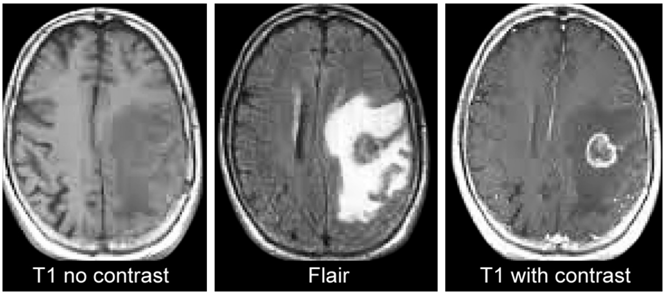


Fig. 9.8: Contrast magnetic resonance imaging (MRI) of skull without contrast and with contrast medium introduced.

smaller vessels. Because of hydrophilic nature of the gadolinium chelates, they do not pass through the blood brain barrier and thus enhance the lesions wherever there is a leak in the blood brain barrier, caused by the tumor growth. In the rest of the body, the contrast medium may enter into interstitial space and finally it is excreted out though the kidneys.

Disadvantages of Gadolinium

- It is NOT safer than the contrasts of iodine compounds
- Anaphylactic shock has not been seen in about 0.02 to 0.1% of cases.
- It is toxic if it is not used in chelated form.
- The contrast agents containing gadolinium are—omniscan, magnegita, gado–MRT-ratiopharm (brand of gadopentetate dimeglumine is the N-methylglucamine salt of the gadolinium complex of diethylenetriamine penta acetic acid is an injectable contrast medium), optimark, magnevist, etc. These compounds were banned as they caused renal damage. These drugs are contraindicated in people with kidney disease, recent liver transplants, new born babies of one month of age.

Other compounds used are, iron oxide, iron platinum, manganese, barium sulfate, air, clay, blueberry, green tea, perfluorocarbon and any other natural agents, which reduce the hydrogen ion in body cavity are used. If there is more hydrogen the area appears white and if here is less or no hydrogen ion in the part to be examined the image will be from shades of grey to dark (black) (Fig. 9.8).

MAGNETIC RESONANCE ANGIOGRAPHY (MRA) (FIG. 9.9)

It is an advanced technique in which the study of blood vessels is done. In this test, a powerful magnetic field, radio waves and a computer create a detailed image. This procedure does not use X-rays. It can be performed with or without the contrast material.

Gadolinium compounds are used as contrast material in magnetic resonance angiographic study.

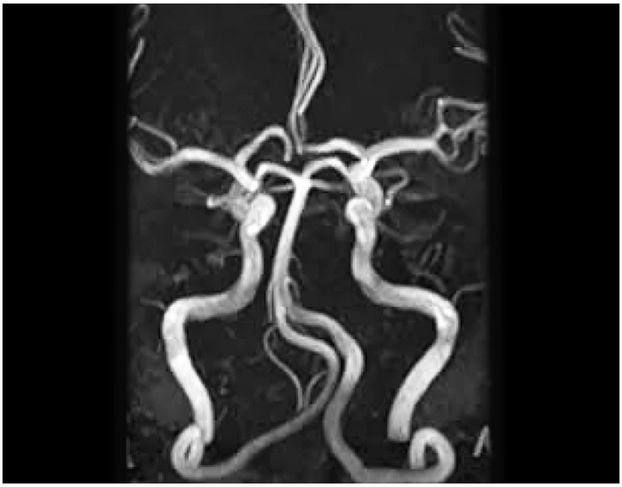


Fig. 9.9: Magnetic resonance angiography (MRA) of the carotid and vertebral arterial systems supplying the brain.

The MRA is required in the following cases:

- The organs which are highly vascular and susceptible for microvascular damage are studied by this procedure. For example, vessels of kidneys, liver, heart, brain, thorax, pelvic of upper and lower limbs
- This procedure helps in identifying aneurysms
- Atherosclerotic changes
- Abnormal communications between artery and vein
- Before the preparation for endovascular surgery for repairing the diseased blood vessels, introducing stents, coronary bypass surgery or for evaluation after the stent is being placed
- Visualization of the abdominal organ before and after being transplanted to see the establishment of circulation
- In case of severe injuries of limbs, neck, chest, abdomen, pelvis to evaluate the involvement of blood vessels in that region
- In case of tumors to study the arteries prior to surgery or after internal radiation therapy
- Detect embolism in pulmonary vessels or to see blood clots anywhere along the area of supply
- Also used to study some of the malformations of heart and great vessels in case of children
- This procedure is a must in individuals who are with a family history of vascular disease/ disorder.

It is contraindicated in pregnancy, lactation, in patients with implants like cochlear implant, clips in brain, metal coils in the blood vessels and cardiac pacemakers. In claustrophobic patients, children or in anxiety patients a mild sedation is required to be administered.

The jewels, credit cards, watch, pen, coins, body piercings, external dental fixtures and hearing aids should be removed.

While in the magnet, the radio waves redirect the alignment of hydrogen atoms which exist in the tissues of the body without causing any chemical changes in the tissue. Now these hydrogen atoms emit energy and create an image of the tissue scanned. The computer processes these signals which are sent and received radio waves and shows a thin slice of the part or the body. Different angles can be used to study the tissue from all aspects. The contrast medium which has been introduced in to the blood vessels defines the vessels by making them brighter (white). The entire procedure may take about 45 minutes to an hour or more.

Advantages

- No exposure to X-rays
- Safe contrast media
- Magnetic resonance angiography procedure is a short process than the traditional angiogram
- Less costly than angiography done using catheters
- There is no need to introduce any catheter for the procedure
- Even without using the contrast material, the procedure can be carried out in case of allergies and renal diseases.
- The recovery period is very short.

Disadvantages

- Strong magnetic fields are harmful in case of cardiac, vascular, ear, dental implants and will become disabled
- The contrast medium, gadolinium compound may be allergic in few cases and may lead to development of nephrogenic systemic fibrosis—a complication
- In case of anxiety and claustrophobia the sedated patients are to be constantly monitored and chances of excess sedation can be seen
- Not advised in pregnancy and lactation.

Limitations of Magnetic Resonance Angiography (MRA)

- There should be total immobility during the procedure for a long time so cannot be done in cerebellar or basal ganglia disorders
- Any type of motion including the breathing movements may cause distortion of the images
- The procedure is difficult in individuals whose body size cannot fit into the machine
- Does not detect calcium deposits
- It is difficult to create separate images for artery and vein
- Injecting contrast material in pregnant women is contraindicated except in cases where it is a must in the diagnosis and treatment of pregnant women.

10

Radiology: Upper Limb

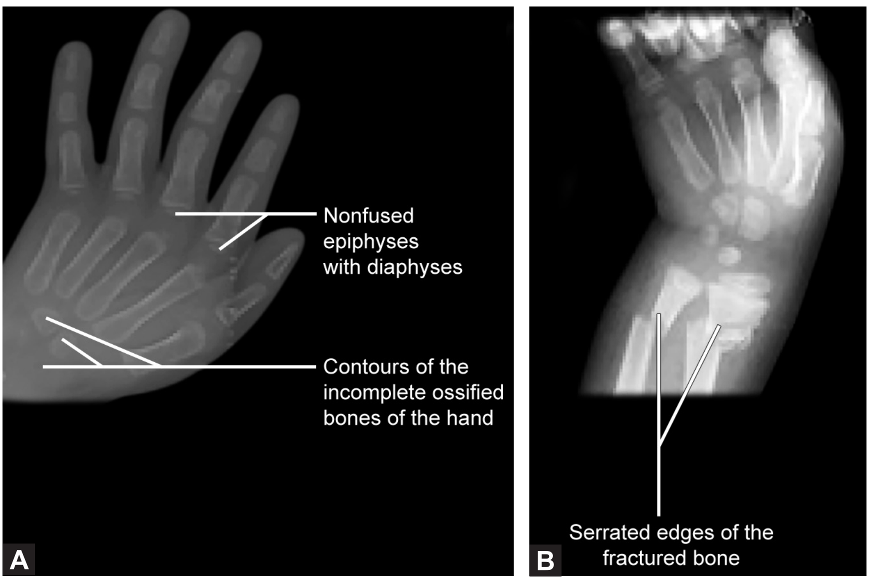
Usually the limb radiographs are taken as plane radiographs to either assess the age by looking at the unossified parts, ossification centers and nonfused epiphyses or to note the fractures of the bones.

The contrast radiographs of the limbs are usually the angiograms.

The age assessment is done by taking the radiographs at the joints which involve more than one bone.

Applied Anatomy

The gap between the epiphysis and diaphysis might be mistaken for fractures especially during younger ages. This can be ruled by observing for the smooth contours. The contours of the epiphyses and diaphysis appear smooth whereas the fractured ends of the bones appear irregular and serrated, smooth contours of the bone fragments in case of nonfusion diaphysis and epiphysis (Fig. 10.1A) and serrated ends of fragments in case of fractures of the bone (Fig. 10.1B).



Figs. 10.1A and B: (A) Smooth contours of the shadows of bones indicating nonfusion of the bones and incompletely ossified bones; (B) The fracture of the bones with serrated ends.

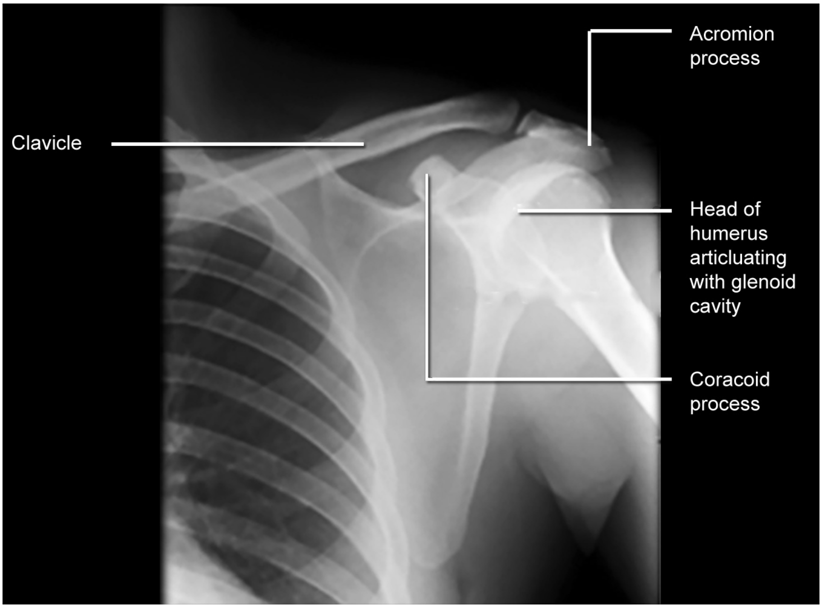


Fig. 10.2: Plane radiogram of the shoulder region posteroanterior view. Fully ossified scapula, upper end of humerus, lateral part of clavicle, parts of ribs, acromioclavicular joint and glenohumeral joint are visualized.

SHOULDER REGION (FIG. 10.2)

This is usually a plane radiograph to study the shoulder joint. In this radiograph the head of humerus, glenoid cavity and parts of processes of scapula are visualized. The view selected is anteroposterior or posteroanterior. The acromion process, coracoid process and part of the lateral border of scapula are visible. Radiographs before the age of 16–17 years show nonfused epiphysis. The ends of the bones and their level of ossification help in assessing age.

ELBOW (FIG. 10.3)

The plain radiographs with anteroposterior and lateral views are taken to study the lower end of humerus and upper ends of radius and ulna.

Radiograph shows the lower end of humerus and upper ends of radius and ulna the center for the medial epicondyle appears at the age of 6th year and fuses separately with the shaft at 20th year. **It does not obey the law of ossification which states that if there are multiple secondary centers they fuse with each other to form a single epiphysis that fuses with the diaphysis.**

WRIST AND HAND (FIG. 10.4)

For the plane radiographs of the wrist, anteroposterior view, lateral view and semi-prone view are usually taken. This is used to study the lower ends of radius, ulna, carpal bones, metacarpals and phalanges.

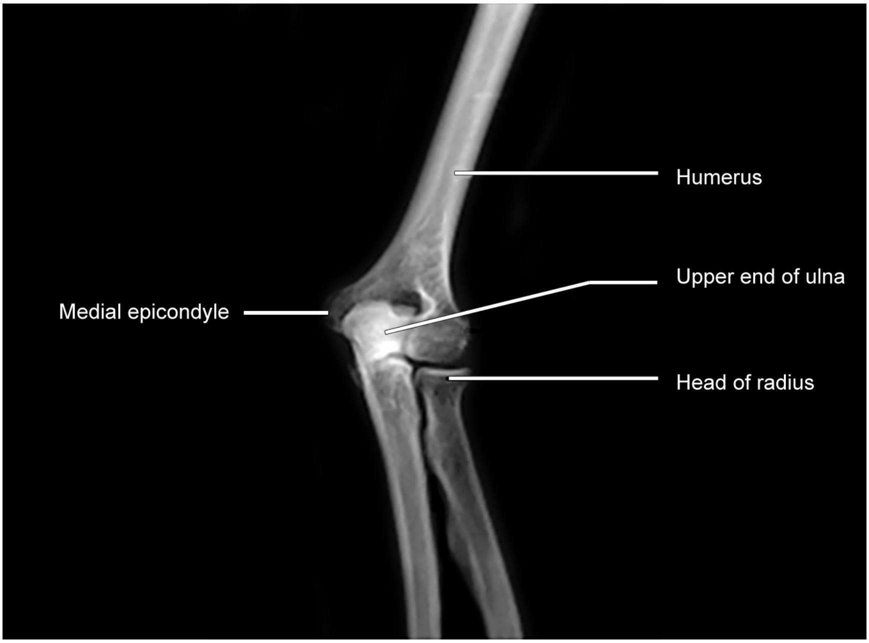


Fig. 10.3: Plane radiogram of the elbow region posteroanterior view. The elbow joint and superior radioulnar joint are visualized.

Fig. 10.4: Plane radiograph of a hand showing the shadows of lower ends of radius and ulna, carpals, metacarpals, and phalanges.
(PH: Phalangeal bone; MC: Metacarpal bone; TZ: Trapezoid; C: Capitate; H: Hamate; TQ: Triquetral bone; P: Pisiform; T: Trapezium; S: Scaphoid; L: Lunate; U: Ulna; R: Radius).

Table 10.1: Shows the age at which the centers of ossification appear in carpal bones.

Sl. No.	*Carpal bone*	*Age of appearance*
1.	Capitate and hamate	1st year
2.	Triquetral	3rd year
3.	Lunate	4th year
4.	Scaphoid, trapezium, trapezoid	5th–7th year
5.	Pisiform	9th–12th year

Fig. 10.5A: Plain radiograph of a child between 7 and 9 years of age.
(H: Hamate; C: Capitate; R: Lower end of radius; U: Lower end of ulna; S: Scaphoid; TZM: Trapezium; and TPZD: Trapezoid).

The ossification of carpal bones is in a spiral manner and the first bones to ossify are capitate and hamate. The triquetral, lunate, scaphoid, trapezium, trapezoid follow gradually and the last bone to ossify is pisiform. Table 10.1 depicts the carpal bones and their age of appearance.

The medial four metacarpals ossify with one primary center for shaft and one secondary center for the head, whereas the first metacarpal ossifies with one primary center for shaft and one secondary center for the base. The primary centers for the metacarpals appear at 9th week of intrauterine life. The secondary centers appear in the 2nd year in females and 3rd year in males (Figs. 10.5A and B).

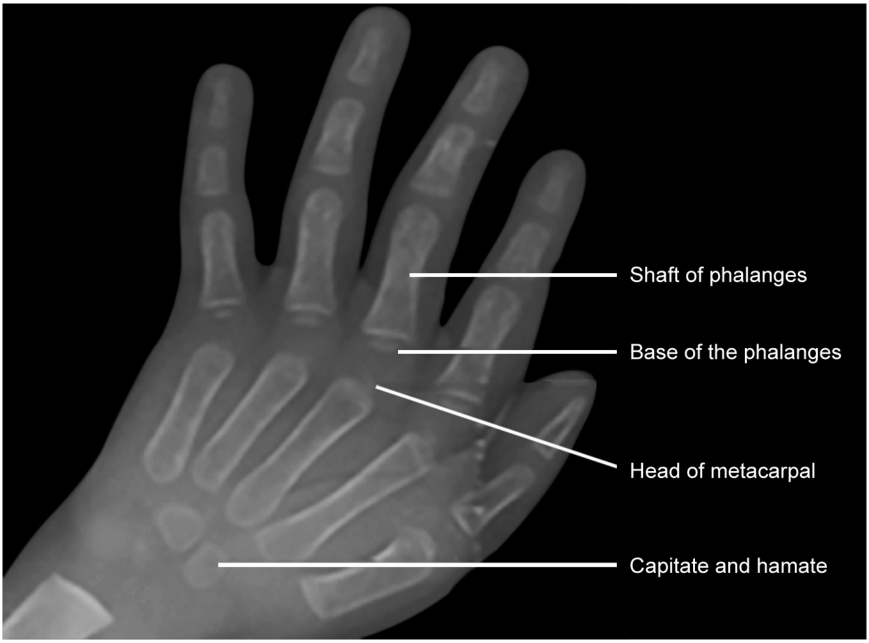


Fig. 10.5B: Plane radiogram of a child between 3 and 5 years of age showing the nonfused epiphyses and diaphyses of metacarpals and phalanges. Only four carpals have appeared.

Fig. 10.6: The plane radiogram of the forearm and hand of a child between the age of 3 and 5 years. There is absence of radius.

The phalanges also ossify with one primary center for the shaft and one secondary center for the base. The primary center appears in 9th week of intrauterine life. The secondary centers appear by third year after birth. They appear at the bases.

The fusion of the epiphyses is completed in the 15th year in females and 17th year in males.

The ossification of the radius and ulna is also peculiar and easy to remember. It is like letter "N". First secondary center appears for the lower end of radius at 1st year, upper end of radius at 4th year followed by center for the lower end of ulna at 5th year (4 + 1 = 5) and lastly the upper end of ulna at 9th year (4 + 5 = 9). In some cases there may be congenital absence of radius (Fig. 10.6). In that case the other centers are taken into consideration to assess the age of the child.

11

Radiology: Lower Limb

HIP REGION (FIG. 11.1)

Normally viewed in anteroposterior view. The position of the lower limb should be in such a way that there is separation of lower limb at heels and all the toes are directed anteromedially. This position of lower limb allows the femur to rotate slightly medially and femoral neck lies parallel to the radiographic film. In this position the shadows of upper end of the femur and acetabular region are visualized better.

The borders of acetabular cavity and head of femur appear as curved lines indicating the radiodense cortical tissue (compact part) of the bone. The shadow of the thick cortical tissue of the medial edge of the acetabulum can be traced above which becomes continuous with pelvic brim shadow and below it ends just above and lateral to the obturator foramen margin.

Fig. 11.1: Plane radiogram of pelvis, lower lumbar region and hip joint, anteroposterior view. (I: Ilium; A: Acetabular cavity; F: Head of femur; GT: Greater trochanter; LT: Lesser trochanter; P: Pubis; PS: Pubic symphysis; OF: Obturator foramen; IP: Ischiopubic ramus; IS: Ischium; NSA: Neck shaft angle).

The joint space in the hip joint appears radiolucent and has been measured to be between 4 mm and 7 mm. The shadows of posterior border of acetabulum and fovea capitis of femur are also visible in the radiograph. The shadows of the neck, greater trochanter and the lesser trochanter of femur are visualized. The shadow of the neck of the femur is more horizontal i.e. in coronal plane when the toes are directed medially with both feet apart. The shadow of the lesser trochanter becomes prominent when the leg is rotated laterally and toes are directed laterally.

In normal anteroposterior view, two curved lines can be appreciated.

1. ***Shenton's line (Fig. 11.2)*****:** Line at the upper margin of obturator foramen that becomes continuous with the shadow of inferior surface of the neck of femur and the medial border of shaft of the femur till lesser trochanter shadow.
2. Another line can be drawn along the external border of the ilium and upper border of the neck of femur (Fig. 11.2).

These two lines are not altered on change of the posture but **discontinuity in the curved lines is seen in fractures of neck of femur or in dislocations of hip joint.**

The **neck shaft angle** can be visualized when the foot is slightly turned medially. Its measurement varies between **120° and 135°**. It is **less than 120 degrees in coxa vara and more than 135 degrees in coxa valga** depending upon the age, pelvic width and stature. The shadows of trabeculae caused due to pressure present a peculiar patterns and help in assessing the amount of calcification of the bone.

Fig. 11.2: Plane radiograph of the pelvis and hip region, posteroanterior view, showing the Shenton's line (A) and another curved line extending from external aspect of ilium below posterior superior iliac spine to the upper border of the neck of femur till greater trochanter (B).

Age Changes

- After birth, center for the head is seen at 1st year of life. Greater trochanter at 3rd year and lesser trochanter between 9th and 10th year.
- The ilium, ischium and pubis appear as separate bones which are joined by a triradiate cartilage at acetabulum.
- The junction between ischial ramus and inferior ramus of pubis has a cartilage. The fusion of ischiopubic rami takes place postnatally between 7 and 8 years.
- An accessory center may appear for the lateral border of acetabulum. Sometimes it fails to fuse with acetabulum and remains separately as **os acetabulare**.

KNEE JOINT

Normally anteroposterior and lateral views are taken.

Anteroposterior View (Fig. 11.3)

The borders of the bones taking part in the joint formation present a smooth, white line (radiopaque line) which is due to the presence of thin cortical bone tissue.

- The joint space appears as radiolucent area—about 3 to 5 mm vertically, superimposed patellar shadow is seen on the shadow of lower end of femur the medial and

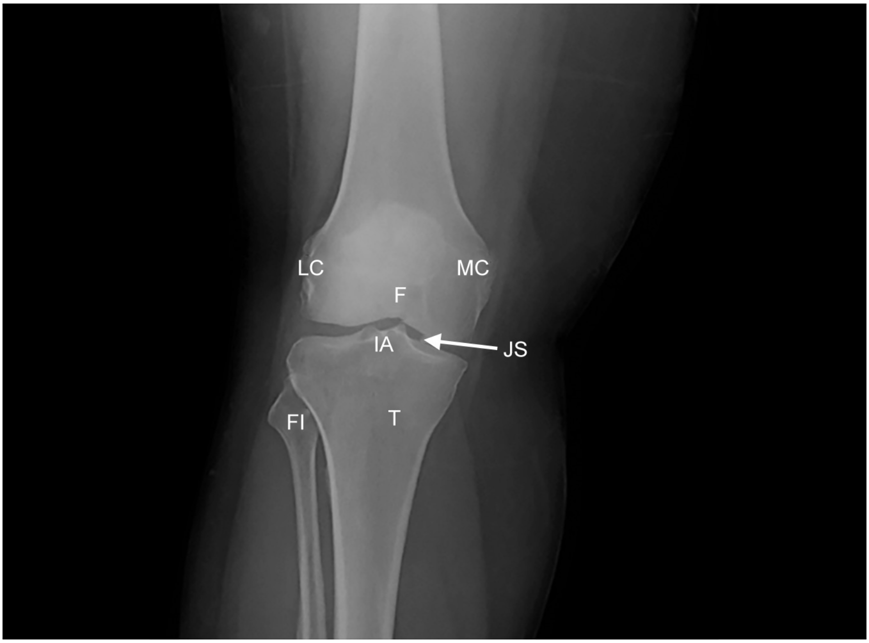


Fig. 11.3: Plane radiograph of the adult knee anteroposterior view. Shadows of lower end of femur and upper ends of tibia and fibula. Rounded radiopaque shadow at the lower end of the femur superimposing the lower end of the femur is that of patella.
(F: Femur-lower end; LC: Lateral condyle; MC: Medial condyle; T: Tibia; FI: Fibula; IA: Intercondylar area; JS: Joint space).

lateral condylar shadows of femur are seen on either side of the lower part of patellar shadow.

- The lateral border of the lateral condyle of the femur presents a notch which represents the groove for the popliteus muscle.
- The intercondylar area of tibia presents shadows of intercondylar spines between medial and lateral semilunar areas which are covered by menisci (semilunar fibrocartilages).
- Sometimes a small shadow of sesamoid bone is seen close to the origin of lateral head of gastrocnemius (close to lateral condyle of femur) and is called **FABELLA**. It usually measures about 5 mm in diameter.
- Shadow of upper end of fibula is seen close to the lower part of the lateral condyle of tibia.

***Lateral view (Fig. 11.4)*:** The patellar shadow can be seen anterior to the lower end of femur. In complete flexion of knee joint the patellar shadow comes to lie distal to the condylar shadows of femur. The shadows of medial and lateral condyles of femur are superimposed and the same with the condyles of tibia. The shadow of upper end of fibula and condylar shadows of tibia are also superimposed.

The shadows of the shafts of tibia and fibula show shades of grey and white. The white shadows are of outer border of cortical tissue. The spongy part appears grayish and the marrow cavity appears radiolucent. In lateral view of leg, the shadow of fibular shaft appears posterior to the shadow of tibial shaft.

Fig. 11.4: Plane radiograph of the knee in the lateral view. Shows shadows of lower end of femur and upper ends of tibia and fibula.
(F: Femur-lower end; T: Tibia; FI: Fibula; P: Patella).

Developmental Changes

- The shadows of lower epiphysis of femur and upper epiphysis of tibia are seen at the time of birth as they are present at full term pregnancy.
- The upper epiphysis of fibula is seen at the age of 3 to 4 years of age.
- The patellar ossification occurs with multiple secondary centers at the age of 3 years which soon fuse to form a single mass.
- The tibial tuberosity appears around puberty and fuses to the upper epiphysis and appears like tongue shaped projection directed downwards on the anterior aspect of the upper end of the tibial shadow.

ANKLE JOINT (FIGS. 11.5 AND 11.6)

In anteroposterior view, the shadows of lower ends of tibia, fibula, talus, calcaneum, navicular, cuboid and cuneiforms are seen. The shadow of ankle joint with lower ends of tibia, fibula (medial and lateral malleoli) and upper end of talus are seen. Joint cavity appears radiolucent. The lateral malleolar shadow extends slightly beyond the medial malleolar shadow.

In lateral view, the lower ends of tibia and fibula are superimposed. The shadow of subtalar joint (talocalcaneonavicular joint) can be seen clearly. The shadows of cuboid overlapping the shadows of cuneiform are seen.

Fig. 11.5: Plane radiograph of adult foot in superoinferior view. Tarsals, metatarsals and phalanges are visualized.
(P: Phalanx; MT: Metatarsal bone; CU1: Cuneiform-medial; CU2: Cunciform-intermediate; CU3: Cuneiform-lateral; N: Navicular; T: Talus; C: Cuboid; MM: Medial malleolus; LM: Lateral malleolus).

Fig. 11.6: Plane radiograph of adult foot in lateral view showing the lateral aspect of the ankle joint, tarsals, metatarsals and phalanges.
(P: Phalanx; MT: Metatarsal bone; CU: Cuneiforms-superimposed; N: Navicular; Ta: Talus; C: Cuboid; CA: Calcaneum; T: Tibia; F: Fibula).
Sources:
1. https://en.wikipedia.org/wiki/X-ray_generator
2. www. acrin.org to a mammography machine
3. www. rehabmedicalequipments.Trolley ultrasound machines
4. www.medwow.com higher CT slice counts
5. www. en.wikipedia.org MRI scanner
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FOOT (FIGS. 11.6 AND 11.7)

In this the shadows of tarsal bones, metatarsals and phalanges are seen. The fifth metatarsal bone presents a projection called styloid process. Calcaneocuboid joint, talonavicular joint can be well-appreciated. Shadows of sesamoid bones are seen near the plantar surface of distal end of first metatarsal bone.

Age Changes

- The center for the lower end of tibia at 4th year and for lower end of fibula at 1st year of life.
- Shadows of centers of ossification in calcaneum, talus and shafts of metatarsals are seen at birth.

Fig. 11.7: Plane radiograph of adult right foot viewed from above.
(SB: Sesamoid bone; TN: Talonavicular joint; CC: Calcaneocuboid joint).

- Center for cuboid appears immediately after birth, for cuneiforms between 3 and 4 years, for navicular at 4th year, for metatarsal heads of lateral four and base of first metatarsal at the age of 3 or 4 years. There may be an epiphysis which appears at 10th year.
- Sometimes there may be an additional epiphysis for the lateral border of base of fifth metatarsal bone. It lies parallel to the long-axis of shaft of 5th metatarsal bone. Stress lines of trabeculae can be appreciated in calcaneum.

12

Radiology of Thorax

Radiographic examination of thorax is done to see the thoracic cage, the lungs, bronchial tree, hilum and roots of lungs, heart, great vessels, and the mammary glands.

The radiologic study of thorax includes, plane radiograph and contrast radiograph.

The plane radiograph of chest (thorax) is taken with a normal distance of 2 meters between the X-ray tube and the film which prevents scattering of the rays and distortion of the shadow.

In plane radiography of chest there are various views in which the radiographs can be taken. They are—anteroposterior (AP) view, posteroanterior (PA) view, right lateral view, left lateral view, right oblique view, and left oblique view.

The most preferred views are PA view and lateral views.

In ***posteroanterior view (PA view or anterior view)***—the person is usually standing or can be sitting with straight back. The film is kept on the anterior aspect of the chest and the X-ray tube is behind. The distance between X-ray tube and the film is 2 meters (6 feet) to avoid distortion of the shadow. The center of the X-ray beam is directed to the tip of the spine of the 4th thoracic vertebra. The exposure time is calculated to be 1/10th of a second to prevent blurring of the shadow due to the movements of heart and lungs. The position of the person whose radiogram is to be taken is as follows:

1. Overhead abduction at shoulder with both hands on the back of the head or both dorsums of hands kept on the upper gluteal regions.
2. In both cases the elbows should be directed anteriorly. This prevents the overlapping of the shadows of scapulae on the lung fields.
3. The shoulders should be symmetrically placed.
4. At the time of exposure to the X-rays the person is instructed to take a deep breath and hold the breath for few seconds to cause immobility of lungs during respiration.

In such radiographs the lung fields, cardiac shadow, shadows of trachea and great vessels, skeletal shadows and soft tissue shadows are seen which include mediastinum, diaphragm, sub-diaphragmatic area, mammary glands, etc.

LUNG SHADOW (FIG. 12.1)

The lung fields and tracheal shadows are radiolucent and appear black on grey scale. The skeletal shadows are radiopaque and appear white on grey scale. The remaining soft tissue shadows are of varying shades in grey scale depending upon the density and presence of air and water content of the tissue.

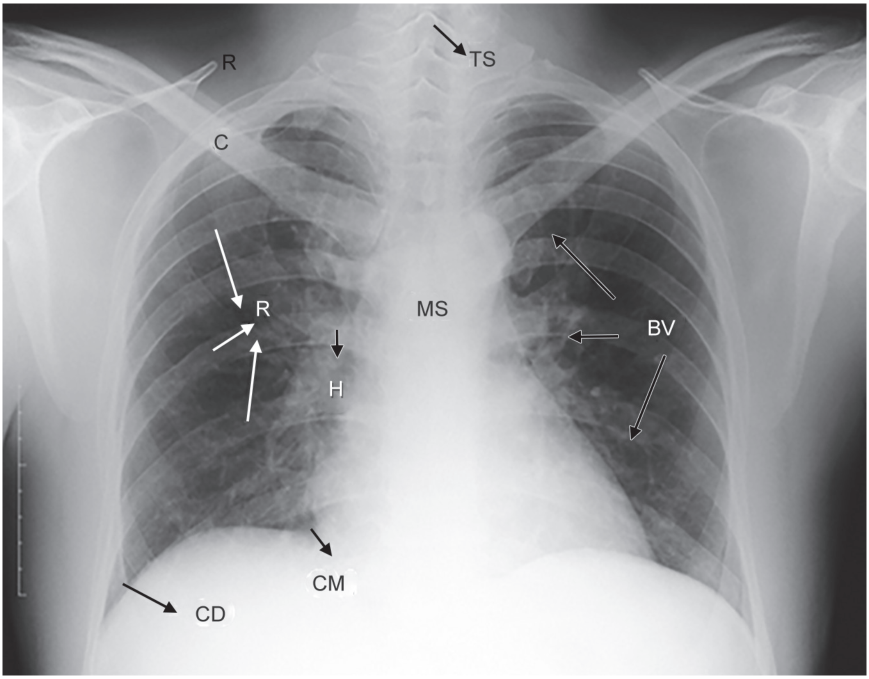

Fig. 12.1: Plain radiograph of thorax, posteroanterior view.
(C: Clavicle; R: Ribs; TS: Tracheal shadow; H: Hilum; BV: Bronchovascular markings; CD: Costodiaphragmatic recess; CM: Costomediastinal recess; MS: Mediastinal shadow caused by pericardium, heart, and great vessels).

The lung fields contain shadows of pulmonary vessels, bronchial vessels, bronchopulmonary lymph nodes which are arranged from the hila of the lungs to the peripheral parts of the lung fields. The costodiaphragmatic and cardiophenic angles can be seen in this view. The costodiaphragmatic angles contain costodiaphragmatic recesses of the pleurae. The right cardiophrenic angle is acute and contains terminal part of inferior vena caval shadow. On the left side it is the apex of the heart and is again acute normally. The lung fields are crossed obliquely by shadows of ribs.

Applied Anatomy

Pleural effusion: When there is accumulation of fluid in the form of blood, lymph serous fluid in the pleural cavity, it is called pleural effusion (Hydrothorax). This is appears as haziness in the lower zones of the lung. The costodiaphragmatic and costomediastinal recesses are the first one to get obliterated.

In cases of hydropneumothorax, there is accumulation of fluid as well as air in the pleural cavity. This can be differentiated from hydrothorax by the following features.

a. In hydrothorax, the upper limit of effusion appears concave (Fig. 12.2A).
b. In hydropneumothorax, the upper limit of effusion appears as a transverse line indicating the air, fluid level (Fig. 12.2B).

Fig. 12.2A: Plain radiograph of the thorax, PA view. Hydrothorax is present on the left side.

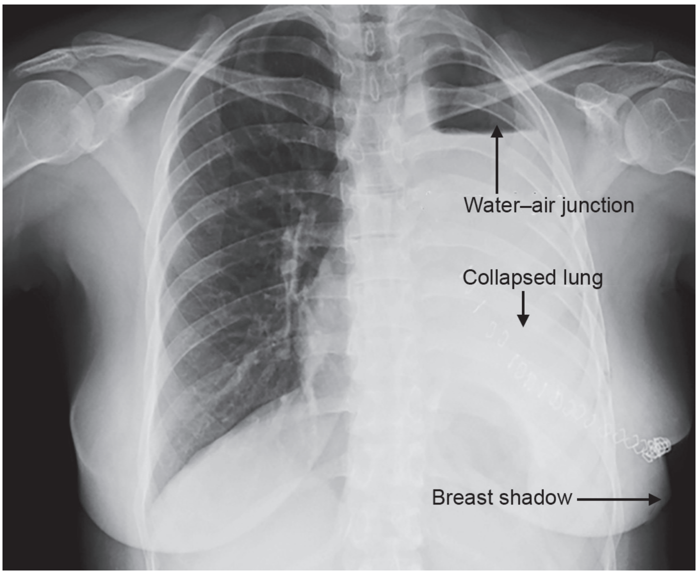

Fig. 12.2B: Plain radiograph of thorax, PA view; hydropneumothorax on the left side.

CARDIAC SHADOW (FIGS. 12.1 AND 12.3)

Cardiac shadow is caused by pericardium, heart, and adjacent great vessels of heart. All of these are together called mediastinal shadow. In the cardiac shadow the right, left and the

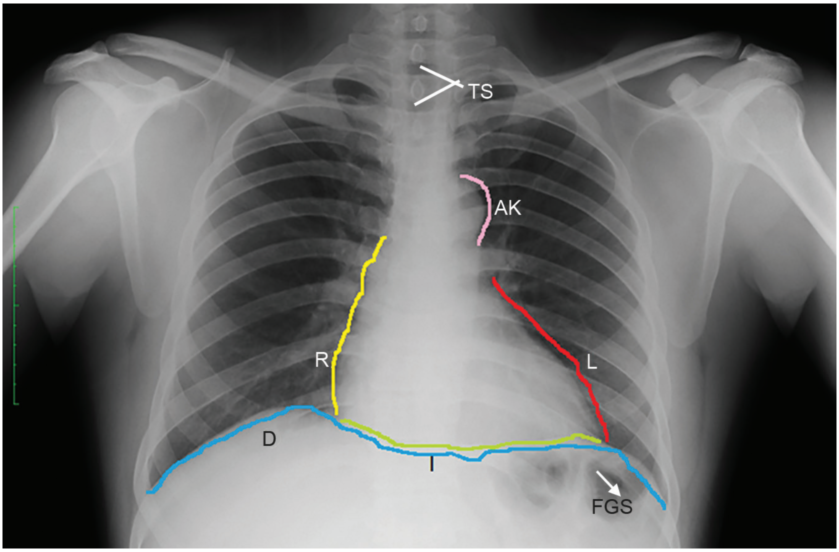

Fig. 12.3: Plain radiograph of thorax. The cardiac area, aortic knuckle (shadow of arch of aorta) and shadows of domes of diaphragm have been marked.
(TS: Tracheal shadow; AK: Aortic knuckle; R: Right border of heart; I: Infeprior border of heart; L: Left border of heart; D: Dome of diaphragm; FGS: Fundic gas shadow).

inferior borders of heart can be appreciated. The pericardial shadow cannot be appreciated due to its close proximity to the heart and the shadow merges with that of heart. The right border is made up of right atrium, which becomes continuous with the right border of superior vena cava and right brachiocephalic vein present in the mediastinal shadow. The left border of the cardiac shadow consists of left ventricle, left atrium, which becomes continuous with pulmonary artery or its left branch, left subclavian artery and arch of aorta of the left border of mediastinal shadow. The shadow of arch of aorta is convex to left and is called **aortic knuckle**.

CARDIAC SIZE ESTIMATION (FIGS. 12.4 AND 12.5)

In the PA view the size of the heart can be calculated and is as follows:

1. Mid-sagittal line is drawn (D).
2. A horizontal line is drawn from the most convex border on the right side to the midline (A).
3. Another horizontal line is drawn from the most convex part of the left border of cardiac shadow to the midline (B).
4. The distances of both the horizontal lines are added (A+B).
5. The total maximum width of the thorax is taken (C) and compared with the width of the heart. If it is more than 50% of the transthoracic diameter, then cardiomegaly is diagnosed. This is radiological diagnosis of Cardiomegaly (Fig. 12.5).

Normal cardiac shadow = (A+B) < 50% (C)

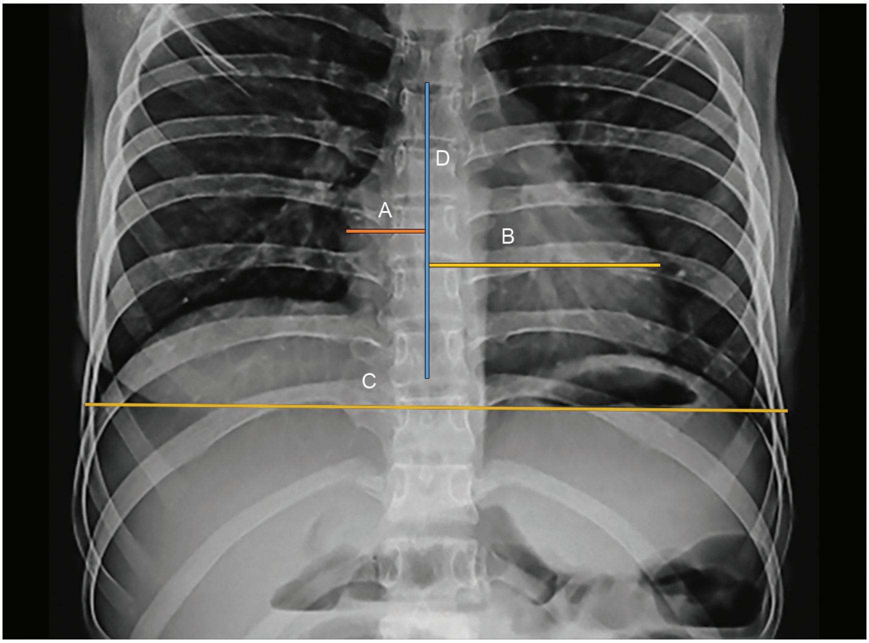

Fig. 12.4: Plain radiograph of thorax in PA view. Estimation of the cardiac size in he radiogram of the thorax (Refer text).

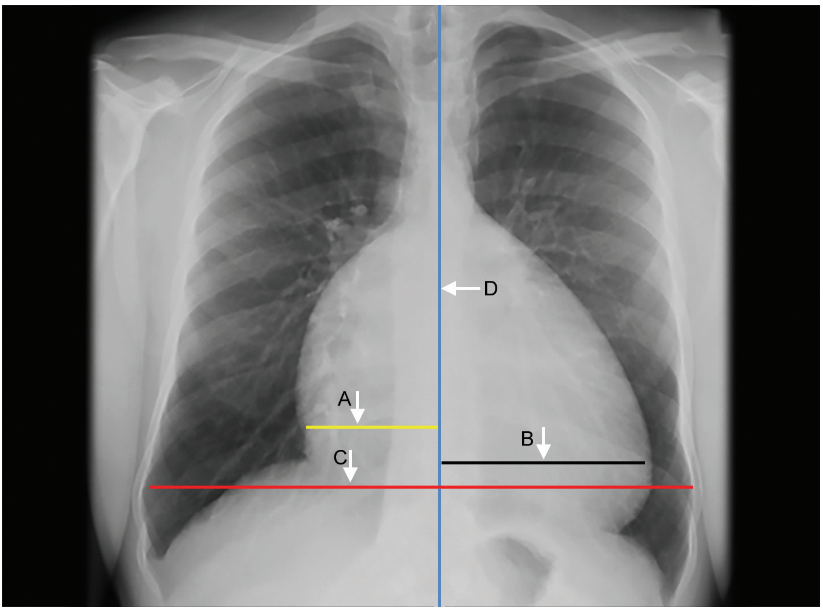

Fig. 12.5: Cardiac size estimation in cardiomegaly in plain radiograph taken in PA view.

The ratio between the cardiac width and the thoracic width varies depending upon the height, stages of cardiac cycle, the respiratory stage and age of the individual in which the radiograph is obtained but it should be between 30 and 60%.

Applied Anatomy

The cardiomegaly (Fig. 12.5) can be assessed by making the measurements and determining the ratio of transcardiac and transthoracic diameters as calculated above. If the transcardiac diameter is cardiomegaly. Cardiomegaly can be due to pericardial effusion, left ventricular hypertrophy, alcoholic myocardiopathy, etc.

MEDIASTINAL SHADOW (FIGS. 12.1 AND 12.6)

The mediastinal shadow includes the great vessels like ascending aorta, arch of aorta, descending thoracic aorta, trachea, sternum, vertebral column, costal cartilages lymphatics and thymus in the upper part.

Shadows of trachea and great vessels, skeletal tissues and soft tissue are seen which include mediastinum, diaphragm, sub-diaphragmatic area, mammary glands, etc.

The tracheal shadow appears as a translucent shadow. The shadows of lower cervical and upper thoracic vertebrae overlap the tracheal shadow; therefore tracheal shadow is masked.

Applied Anatomy

The mediastinal shadow enlargement (Fig. 12.6) can happen due to enlargement of structures present in the mediastinum namely lymphnodes, thymus, etc. Most common enlargement happen due to lymphnode enlargement in hodgkins/non-hodgkins lymphoma/nonspecific lymphadenitis, etc.

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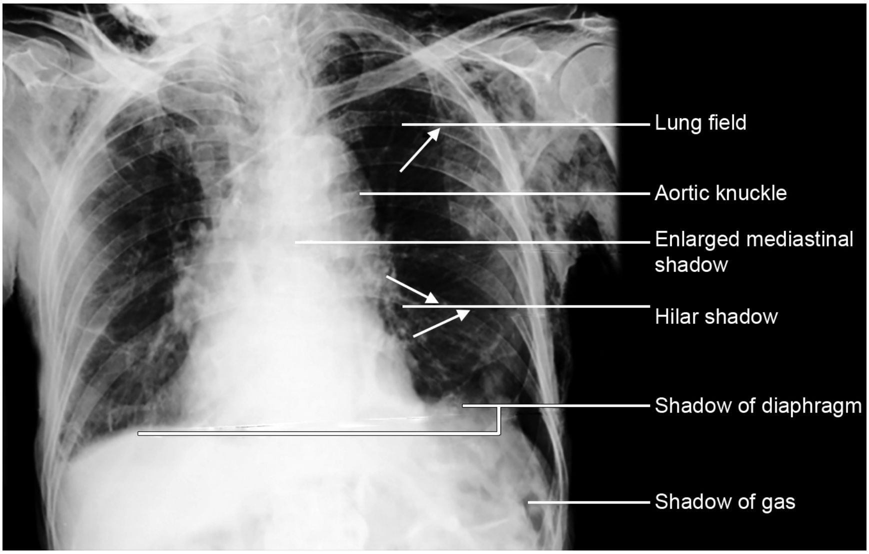

Fig. 12.6: Plain radiograph of the thorax posteroanterior view. Shows enlarged mediastinal shadow.

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***Mediastinal shift*:** If deviation of the central mediastinal shadow to one of the sides. The diseases of the lung like pleural effusion and lung fibrosis can push the mediastinum. In pleural effusion, the mediastinal shifts to the opposite side due to volume increase in the area of pleural effusion.

In cases of lung fibrosis, the damaged lung retracts the mediastinum to the same side due to the contracture caused by fibrosis.

SKELETAL SHADOW (*SEE* FIG. 12.1)

The skeletal or bony shadows are the shadows of clavicles, scapulae, sternum, ribs, costal cartilages and vertebral column. The clavicular shadows cross the lung shadows in the apical part. Posterior ends of the ribs are prominently seen in the upper part and help to count the ribs. The medial borders and inferior angles of scapulae can be appreciated clearly. The sternal shadow is also masked by the mediastinal shadow. The shadows of costal cartilages are not seen unless they are calcified and the shadows of ribs are seen clearly. The posterior ends lie at the higher level than the anterior ends of the ribs. Counting of the ribs is done by tracing the shadows from posterior side to anterior side.

DIAPHRAGM SHADOW (*SEE* FIG. 12.3)

The shadow of diaphragm consists of right and left domes which are convex upwards. The central part of the diaphragm shadow merges with that of heart and great vessels. At the margins there are angles between costal and diaphragm shadows and cardiac and diaphragmatic shadows near the midline. The costodiaphragmatic angles contain the recesses with same name. Cardiophrenic angles contain shadow of terminal part of inferior vena cava (supra diaphragmatic IVC) on the right side and apex of heart on the left side. The vertebral and costal levels of the shadow of diaphragm help in assessing the position of diaphragm. In anteroposterior or posteroanterior view, when the beam of X-ray is passed through the level of highest point of dome of diaphragm, the shadow of highest point of diaphragm is seen at the level of 10th thoracic vertebra and 5th costal cartilage in an average person in normal respiratory position. It can be as high as 1–2 vertebrae (high) or low as 1–2 vertebrae (low). Thus the level of diaphragm helps in knowing the high or low type of diaphragm.

Sub diaphragmatic part is the part of the abdomen and there will be soft tissue shadows of stomach, liver, spleen, kidneys, suprarenal glands, and blood vessels. The liver shadow appears homogenous on the right side (right dome). The gas/air in the fundus of stomach appears on the left side as a radiolucent or dark shadow. If the stomach is visualized immediately after the meal, there will be translucent shadows of air bubbles seen immediately below the left dome which appears as an abruptly ending horizontal opaque area with well-defined transverse level of fluid content of the stomach.

Shadows of mammary glands in females along with the nipples are seen. The mammary glands appear as homogeneous shadow. The nipple shadows are not visible unless they are proponent and appear as circular opaque shadows of 1 cm size in the lower radiolucent lung fields.

Other soft tissue shadows are of muscles like sternocleidomastoids, intercostals, sterno-thyroids, and sternohyoids.

In ***anteroposterior view*****:** The shadows of the structures which are nearer the film appear very prominent. Therefore, the shadows of vertebral column, the posterior parts of the ribs and the scapulae appear very prominently. The medial parts of the scapulae are obscured/ superimposed by the lung fields. The person is usually standing or can be sitting with straight back. The film is behind and the X-ray tube is anteriorly placed. Rest of the instructions are same as that of anterior view.

Lateral view (Figs. 12.7 and 12.8)**:** In this view the person is in standing or sitting position. Arms are raised above the head. The X-ray tube emits rays which are directed to the 6th thoracic vertebra at the level of mid-axillary line.

In **right lateral view**, the tube is on the left side and the film is on the right side.

In **left lateral view** the tube is on the right side and the film is on the left side.

In these views the shadows to be looked for—lung fields, heart and great vessels, trachea, skeletal shadows, and the diaphragm.

The lung fields appear as radiolucent shadows which are overlapped by the shadows of ribs, blood vessels, and hilar shadows. In well-exposed radiograms the fissures of the lungs can be appreciated specially the oblique fissure. In right lateral view the horizontal fissure

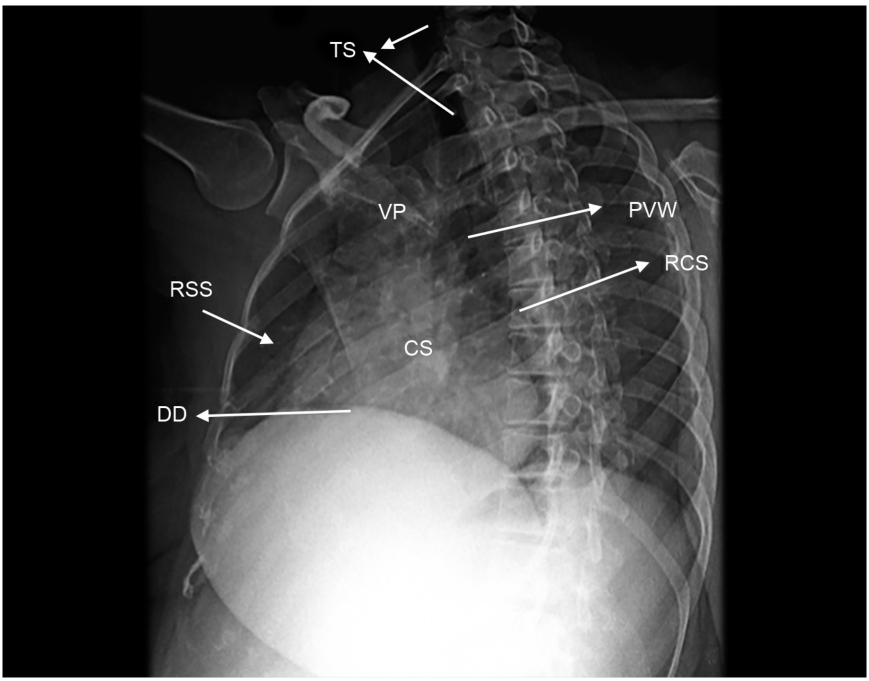


Fig. 12.7: Plain radiograph of the thorax, right lateral view.
(TS: Tracheal shadow; VP: Vascular pedicle; PVW: Prevertebral window; RCS: Retrocardiac space; CS: Cardiac shadow; RSS: Retrosternal space; DD: Dome of diaphragm).

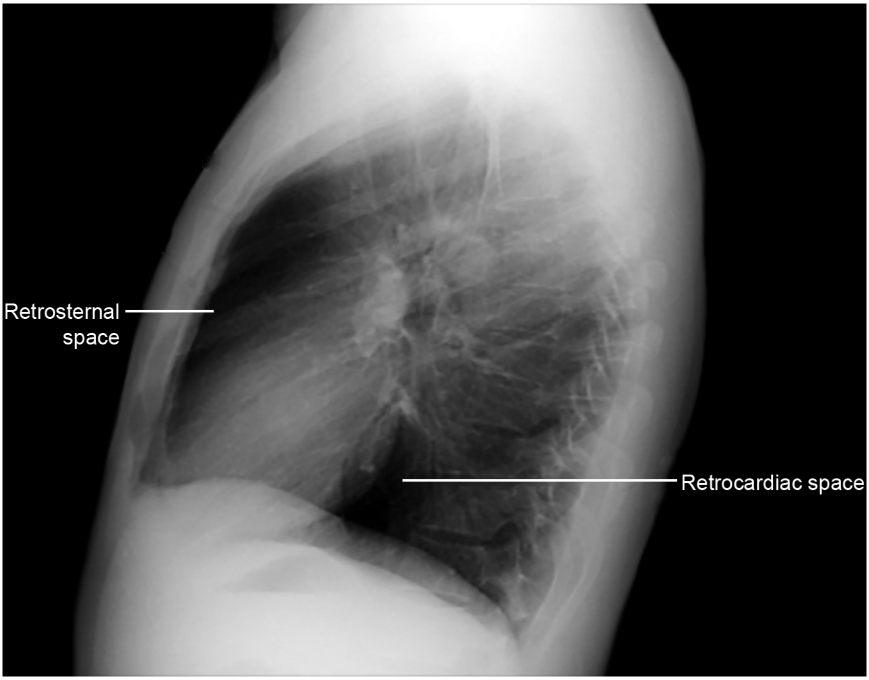


Fig. 12.8: Plain radiograph of thorax, left lateral view.

can be appreciated. These shadows should not be confused with the compact parts of the ribs. The lower and posterior part of the lung field is radiolucent and it is seen to extend slightly below the level of dome of diaphragm because of the left dome slightly at a higher level than the right.

Heart shadow is seen on the anterior part of the diaphragm shadow. Anteriorly there is sternal shadow which is closer to the lower part. In the upper part the same space appears wider and radiolucent. This space is called **retrosternal space** (Fig. 12.7). This is similar to the radiolucent shadow behind the upper part of cardiac shadow and in front of vertebral shadow. It is called **retrocardiac space** (Fig. 12.7). It contains the posterior mediastinal structures and soft tissues which appear as slightly grayish in color in the lung fields. The shadow of esophagus is not seen unless it is filled with a contrast medium. Both retrosternal and retrocardiac spaces appear similar in color.

Tracheal shadow appears as a radiolucent tube due to presence of air inside. The shadow can be seen from its position in neck to the bifurcation which is at the level of 6th thoracic vertebra.

One of the contents of the mediastinum is thymus which is prominent is children and it can be visualized if it is enlarged.

The skeletal shadows are of the bones, cartilages, ligaments, the thoracic vertebrae, intervertebral disks, ribs, sternum and part of the shoulder girdle. Sternal angle is well

defined or well appreciated. In children the body of sternum consisting of sternebrae can be seen. The apical parts of the lungs cannot be visualized due to the overlapping of shadows of overhead abducted arms. Medial border and inferior angle of the scapula can be seen.

The domes of the diaphragm shadow with the highest points lying in front of the mid-axillary line seen. The right dome is at higher level than the left dome. The viscera in the infra diaphragmatic part cause soft tissue shadow and the gas in the fundus appears as a radiolucent shadow in the infra diaphragmatic region.

Oblique View

Consists of right anterior oblique view and left anterior oblique view.

Right Anterior Oblique View (Fig. 12.9)

The tube is on half turned left side of the chest and the film is kept close to the right shoulder. In this view the bronchial tree, esophagus, arch of aorta left side of the heart, skeletal shadows comprising of right clavicle, right sternoclavicular joint, left scapula along with its inferior angle, lateral aspect of the thoracic part of vertebral column and soft tissue in relation to vertebral column are visualized.

Tracheal shadow appears as a radiolucent shadow because of air present inside. There are partial overlapping shadows of both lungs. To further pinpoint to the sides of both lungs, near sternum there is shadow of left lung and close to vertebral bodies is that of right lung. The lung shadows are crossed by the shadows of the ribs.

Fig. 12.9: Plain radiograph of thorax. Right anterior oblique view.

The domes of the diaphragm form the lower boundaries of the thoracic region. The supradiaphagmatic area shows the shadow of heart which is more anteriorly placed. Anterioly the cardiac shadow is very close to lateral sternal shadow. Posteriorly the cardiac shadow is separated from the vertebral column by a radiolucent shadow called the retrocardiac space (space of Holzknecht—named after Austrian radiologist who was a native of Vienna). This space has the contents of posterior mediastinum like the descending thoracic aorta, esophagus, and azygos system of veins, thoracic duct, etc.

The shadow of the ascending aorta is seen arising from the upper part of the cardiac shadow and it extends for a short distance and curves backwards to form arch of aorta.

The tracheal shadow appears as a radiotranslucent, tubular shadow which extends vertically downwards, up to the level of 6th thoracic vertebra, about 4 cm anterior to it and divides into two principal bronchi. Anterosuperior to the shadow of left bronchus there is a round or oval shadow caused by the bifurcation of pulmonary trunk and left pulmonary artery.

Above the level of the arch of aorta shadow there is superior vascular pedicle consisting of brachiocephalic veins, left subclavian artery, left common carotid artery, and brachiocephalic trunk. Between the posterior border of superior vascular pedicle and the vertebral column there is ***prevertebral window***.

Left dome appears prominent with the air shadow in the fundus of the stomach below the shadow of diaphragm.

Left Anterior Oblique View (Fig. 12.10)

In this procedure the film is near the left shoulder and the tube is on the partially rotated right side of the chest.

In this view the shadows of left clavicle, sternum and sternoclavicular joint are seen. Close to the sternum, in the upper part the shadow of right lung is visible. The cardiac shadow close to the sternum is caused by right ventricle and posterior part of the cardiac shadow is caused by left ventricle. Retrocardiac space consists of shadows of contents of posterior mediastinum. Shadow of arch of aorta appears very prominent and continues as descending aorta. Most of the shadow of descending aorta overlaps the shadow of the vertebral bodies. Inferior to the shadow of aortic arch there is a translucent shadow called Parkinson's aortic window. The boundaries of this window are—anteriorly (to viewer's left side) is ascending aorta, posteriorly (viewer's right side) is descending aorta, superiorly by arch of aorta and inferiorly by left atrium. This is traversed across by pulmonary artery and its left branch and divide the area into upper and lower part. Radiolucent tracheal shadow passes vertically downwards through the aortic window.

Above the shadow of arch of aorta, there is a translucent triangular shadow called aortic triangle is seen. Its inferior boundary is arch of aorta, posteriorly bounded by thoracic part of vertebral column and anteriorly by the superior vascular pedicle caused by great vessels lying in superior mediastinum.

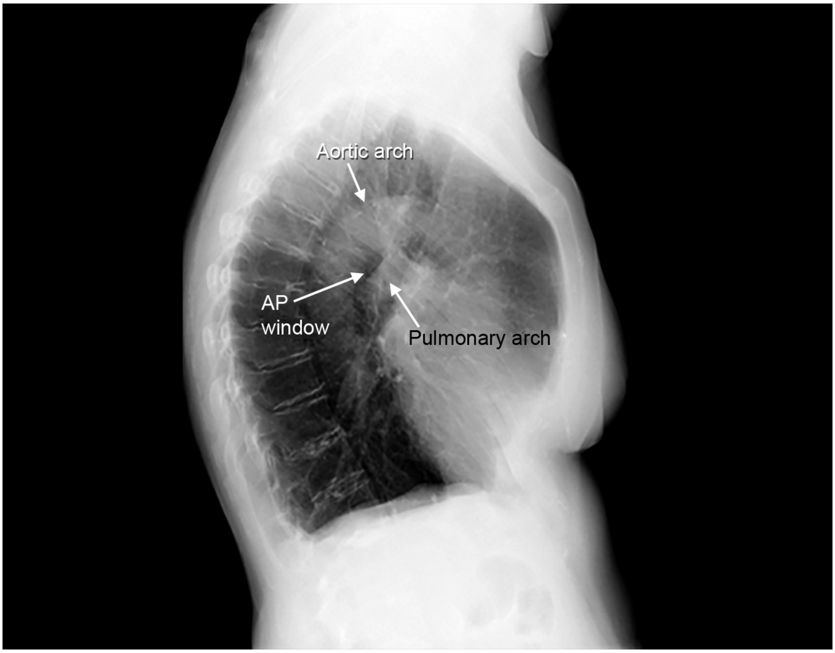


Fig. 12.10: Plain radiograph of thorax. Left anterior oblique view.

In posterior view, a shadow of 5 mm diameter is seen in upper hilum indicating right anterior bronchus. Similarly on the right side the shadows of opening of superior vena cava and the azygos vein can be visualized. Presence of azygos lobe can be made out when present.

CONTRAST RADIOGRAPHS OF THORACIC REGION

1. *To visualize bronchial tree*: Procedure called **Bronchography** is done.
   To visualize cardiac parts: Transesophageal echo—the anterior wall of esophagus lies in close proximity with left atrium (base of heart). This relation helps to carryout trans-esophageal echo through esophagus.
2. *To visualize coronary arteries*: **Coronary angiogram**.
3. *To see the larger vessels*: **Angiograms**—consisting of arteriogram, venogram, and lymphangiogram.
4. *To visualize the esophagus*: **Barium swallow**.

BRONCHOGRAPHY (FIG. 12.11)

To visualize lower respiratory tract (which includes larynx, trachea, and bronchi) a procedure called Bronchography is done. After the invention of CT scans, MRI and bronchoscopy the Bronchography has become obsolete and is done only when it is recommended.

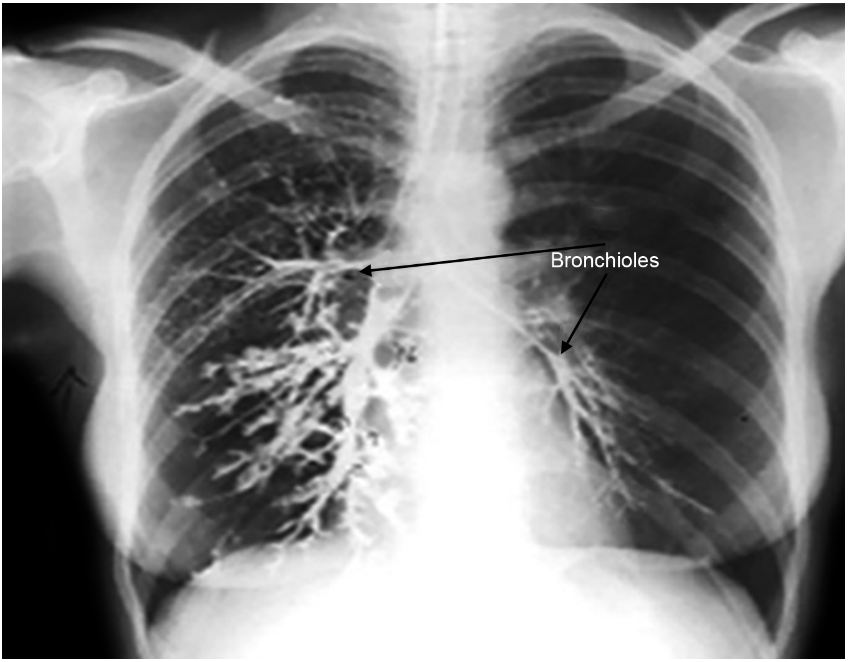


Fig. 12.11: Bronchogram.

It is a procedure where in a contrast medium is introduced into the bronchial tree and radiography is done. The radiograph is taken as soon as the trachea and bronchi are filled with contrast medium. This procedure is done to see the interior of the respiratory tract, growths inside if any and to locate foreign bodies if trapped and the obstruction by the growth or abnormal dilatation of bronchial tree and lungs. It is also done in case of tracheoesophageal fistula. The patient is explained about the procedure. The efficiency of the respiration is assessed.

Before the procedure—patient is to be explained about the procedure and written consent is to be taken by the patient.

- If any medications are taken by the patient specifically the blood thinners like aspirin or any anticoagulants, allergies to medicines containing iodine, latex, local anesthetics, or any other medicines.
- In case of young females menstrual history is to be taken to rule out pregnancy.

Procedure

- A course of antibiotics are administered to the patient for few days before the procedure.
- Sensitivity test for the contrast medium which is going to be used is carried out.
- Nil orally from the night before the procedure.
- Sedative is administered a night before the procedure to avoid anxiety.

- Intramuscular injection of Atropine is administered to prevent secretion. This prevents secretion of glands in the bronchial tree which may cause dilution of the dye and also may induce cough.
- The throat (which includes palate, fauces, posterior part of tongue, posterior pharyngeal wall, all the pillars in the throat, epiglottis, and trachea till carina) is sprayed with 2% local anesthetic 3 to 4 times with an interval of 5–7 minutes.
- This prevents the pharyngeal (gag) reflex and palatal reflex. The patient also complains about inability to swallow.
- A catheter or a bronchoscope is introduced into the throat and passed till the bifurcation of trachea and the radiopaque dye is instilled into the bronchial tree as the catheter is being advanced. There will be discomfort but there will not be any blockage to the airways.
- Then radiographs are taken in various positions. The catheter is removed once all the required radiographs are taken.
- During the procedure, the respiratory rate, blood pressure and the pulse are to be monitored throughout.
- After the procedure the patient is advised not to eat or drink anything till the gag reflex returns to normal.
- Forceful coughing and posture will help in early drainage of the contrast dye.

AORTOGRAM (FIGS. 12.12 AND 12.13)

Radiological visualization of the aorta is called **aortogram**. In this procedure a catheter is introduced into the aorta and a contrast medium is introduced. Radiographs are taken as the radiopaque dye is being introduced into the aorta. Usually the catheter is introduced into the right femoral artery through which the dye is introduced. The reason being the prevention of the spread of aortic dissection into left common iliac artery, as it is the common site of spread of aortic dissection. In aortic dissection the dye which flows into the true and the false lumen of the aorta caused by the intimal flap can be appreciated. In this procedure the extent of the aortic dissection can be diagnosed and if blocks are there they can be treated during the same procedure using different methods. But the pitfall is that in this method iodine dye/compound is used and it is an invasive method that involves larger vessel involvement which may bleed profusely if not careful. Therefore this method has been replaced by newer techniques like CT, MRI and Transesophageal echo which are quickly performed and also non-invasive procedures.

Applied Anatomy

Aortogram is done in order to detect dilatation of aorta called as aneurysms (Fig. 12.13). It can also detect constrictions such as coarctation of aorta.

CORONARY ANGIOGRAPHY (FIGS. 12.14 AND 12.15)

It is an invasive procedure in which a radiopaque dye is introduced into the coronary arteries to visualize the internal features of the coronary arteries by radiographic method.

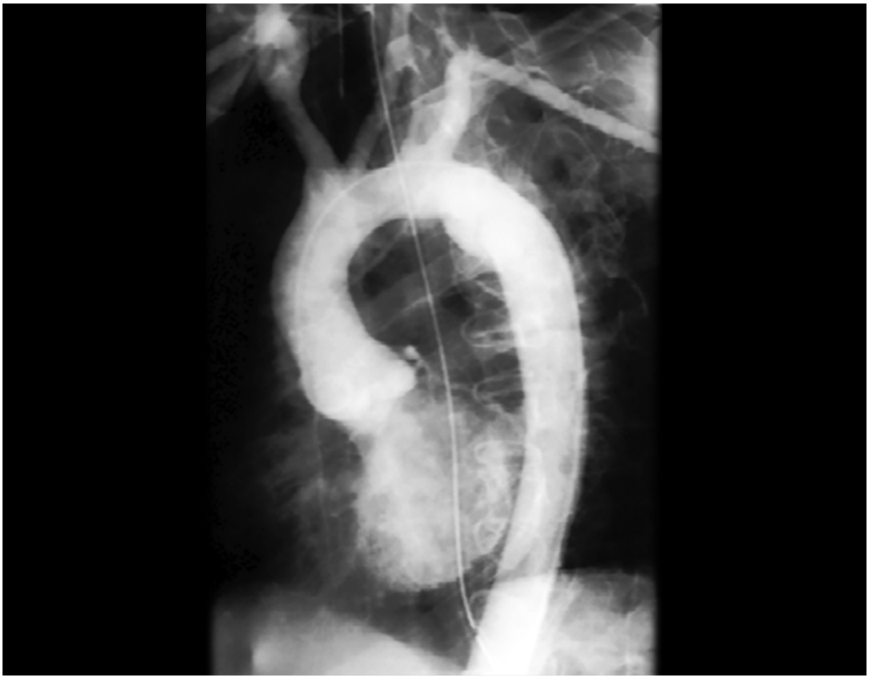


Fig. 12.12: Normal aortogram.

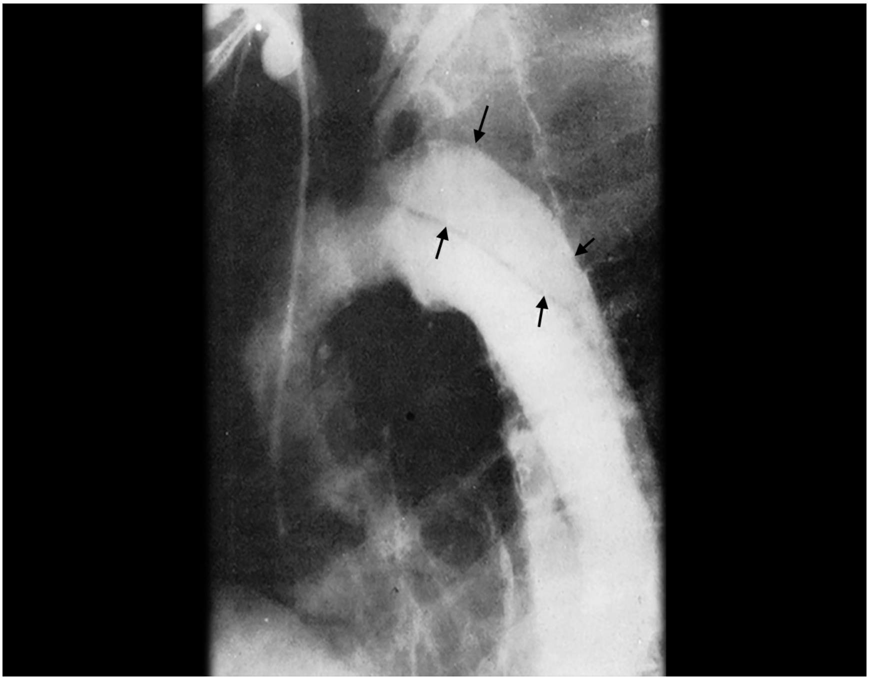


Fig. 12.13: Aortogram in aortic aneurysm.

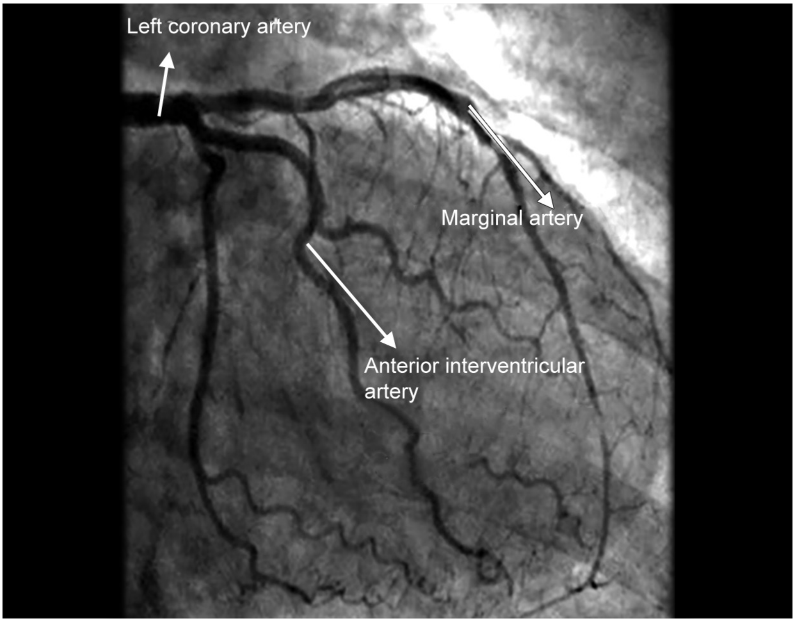


Fig. 12.14: Coronary angiogram. Contrast medium has been injected to study the branching pattern of left coronary artery.

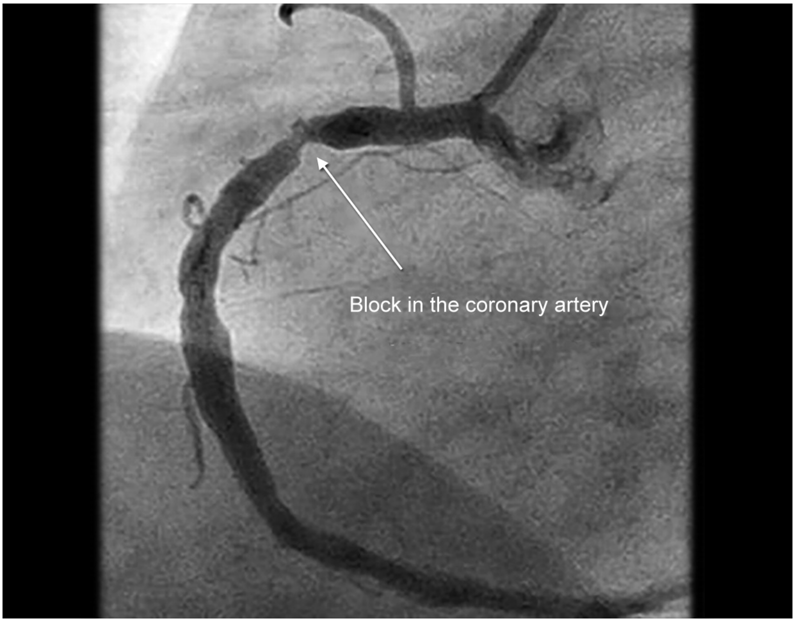


Fig. 12.15: Coronary angiography showing constriction in the shadow of the coronary artery indicating block in the artery.

This test is done to find out the levels of blocks in the coronary arteries if any. The radiopaque dye is introduced by performing a procedure called "cardiac catheterization." For cardiac catheterization, a thin tube is introduced through the radial artery or the femoral artery or one of the carotid arteries. Radiographic pictures are taken as the dye is passing into the coronary arteries. This procedure does not involve general anesthetization. The patient is awake throughout the procedure. Sometimes soreness can be felt in the blood vessels where the catheter has been introduced.

This procedure is done in case of:

1. Unexplained angina
2. Sudden cardiac arrest
3. Abnormal ECG findings—normal or after the stress test (tread mill test [TMT])
4. To perform angioplasty.

Prior to the angiography procedure:

a. Patient is explained about the procedure.
b. Written consent is taken.
c. List of medicines taken by the patient to be collected.
d. Any allergies to any medication, iodine containing dyes, latex, etc., to be found out.
e. In case of females, during fertility period, menstrual history to be taken to find out about pregnancy.
f. Patient is kept nil orally 8 to 10 hours before the procedure if it is a planned one.
g. Sensitivity test for the local anesthetic is to be done.
h. Patient is sedated.
i. The area of the wrist or the front of thigh, where the catheter is being introduced is anesthetized.
j. A small needle is introduced into the artery (radial artery in case of upper limb and femoral artery near the base of the femoral triangle) to pass the catheter which is guided by the fluoroscopy.
k. Dye is introduced into the properly placed catheter and radiographs are taken as the dye is passing into the coronary arteries.

This special radiograph is called the **coronary angiogram**.

Once the procedure is over, the catheter is removed and the opening is closed by a tight bandage. Weight (a small sand bag is put on the bandage) to apply continuous pressure on the artery for better and quick closure of the artery and prevent bleeding through the hole which has been made for introducing the catheter. The patient is advised not to move the area of invasion for about 10 to 12 hours or more to prevent bleeding through the artery. The amount of bleeding, pain, blood pressure, pulse, and heart rate are to be monitored regularly till the patient is discharged.

This procedure is not without any complications. They are pain, bleeding, infection, allergic reaction to the dye introduced. Rarely there may be arrhythmias, kidney damage, low blood pressure, triggering a stroke, heart attack, cardiac tamponade or any serious problems.

Time taken for the whole procedure—30 to 60 minutes.

The result of the test shows the number of coronary arteries, their origin, number of branches, if any block is present and the amount of blockage present.

Applied Anatomy

The coronary angiogram is a most common procedure. It helps in the diagnosis of coronary artery blockage. The angiogram also helps to estimate the percentage of block in each vessel and the number of blocks present. This is important as it helps the cardiac surgeon to decide the mode of treatment such as stent insertion of cardiac bypass surgery.

Radiology: Abdomen and Pelvis

13

In the plain radiograph of abdomen (Fig. 13.1) the shadows of lower ribs, lower thoracic vertebrae, lumbar vertebrae, sacrum and coccyx, hip bones, pubic symphysis are seen. The soft tissue shadows of kidneys, liver, spleen are also visualized as opaque shadows. Gas shadows in the fundus of stomach and in the large intestine appear radiolucent. Plain anteroposterior and lateral views are taken to study the bones, in particular, the lower part of vertebral column from lower thoracic to coccygeal part. The shadows of domes of diaphragm appear as partition between thorax and abdomen. The gas in the fundus of stomach is seen just below the left dome of diaphragm (Fig. 13.2A).

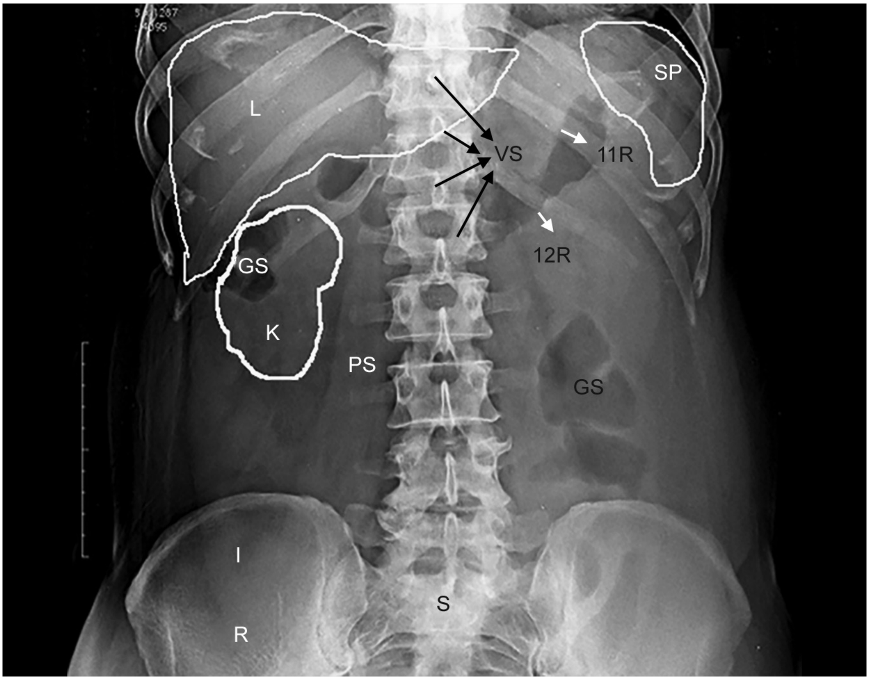


Fig. 13.1: Plain radiograph of the abdomen in anteroposterior view. The outlines of the viscera are marked.
(11R: 11th rib; 12R: 12th rib; S: Sacrum; I: Ilium; VS: Vertebral spine; L: Liver; K: Kidney; SP: Spleen; GS: Intestinal gas shadow; PS: Psoas major).

Applied Anatomy

The plain X-ray of the abdomen is usually taken to detect any bone-related diseases and is the gold standard for the renal stones identification. Skeletal abnormalities can be easily made out by plain X-rays such as kyphosis/scoliosis and lumbar lordosis.

It is also useful to look out for intervertebral disk prolapse, vertebral fractures and other bony fractures of the abdomen and pelvis.

It might also help in the detection of foreign bodies if swallowed or any instruments left during surgery. The foreign body has to be radiopaque in order to be visible in a plain X-ray.

CONTRAST RADIOGRAPH OF ABDOMEN AND PELVIS

Barium Meal (Figs. 13.2A to C)

This procedure is done to study the stomach and the duodenum. Procedure is as follows:

- About 250–300 mL of 50% barium sulfate emulsion is given to the patient to swallow after 6–8 hours of fasting to ensure that the stomach is empty at the time of the procedure.
- As the emulsion reaches the stomach it comes in contact with the mucous membrane and the rugae become visible as radiopaque shadow.
- The ulcers in the gastric mucosa are seen as craters in the shadow.

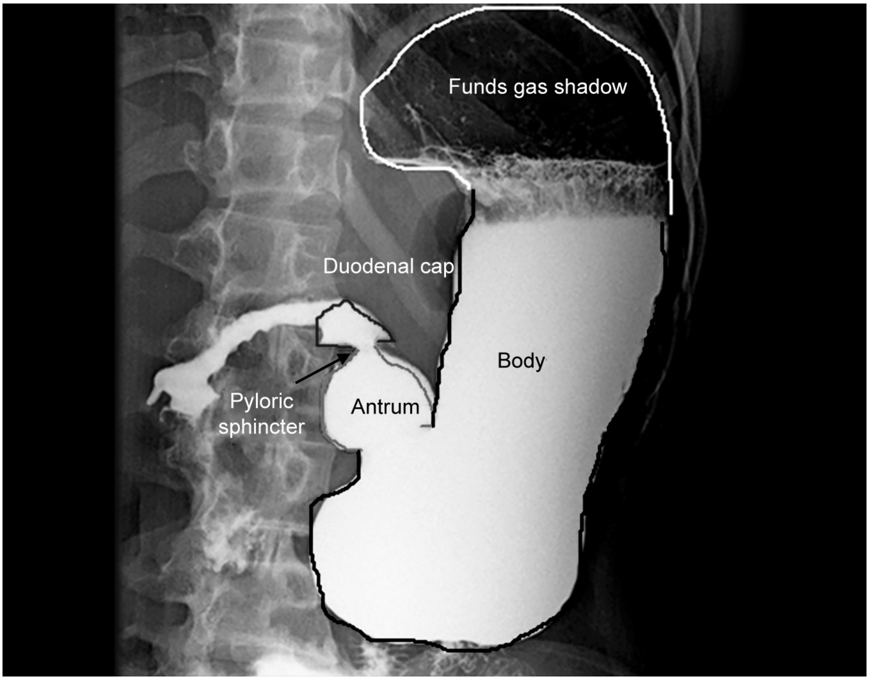


Fig. 13.2A: Contrast radiograph of stomach—barium meal, anteroposterior view.

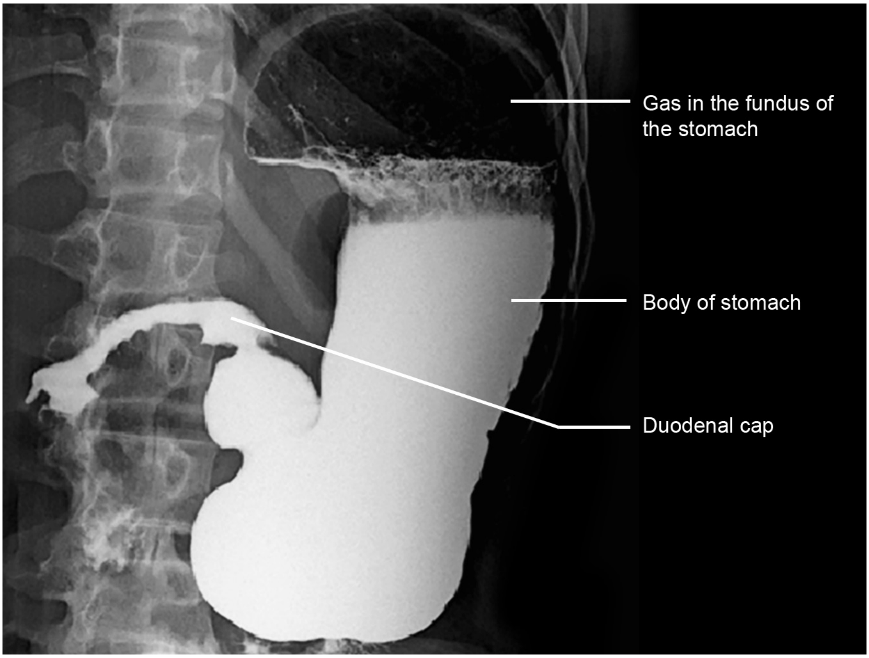


Fig. 13.2B: Barium meal in anteroposterior view. Shows radiopaque shadows of stomach and first part of duodenum (duodenal cap) and adjacent part of duodenum.

Fig. 13.2C: Anteroposterior view of abdomen. Contrast radiograph of stomach (barium meal) showing out pouching on the lesser curvature of stomach indicating diverticulum.

- The shape of the stomach can be appreciated by the shadow and are classified into "J" shaped, steer horn stomach, etc.
- The shadow of stomach depends on shape of the stomach, number of rugae and the size of the stomach.
- In case of normal tone of the musculature of stomach the right and the left walls of the shadow of stomach appear parallel to each other. If the tone of the musculature of stomach is reduced there is sagging of the greater curvature shadow.
- The peristaltic waves appear as soon as the emulsion reaches the stomach and they appear as indentations which are seen within a minute or less. Within few minutes the emulsion reaches the duodenum.
- As the emulsion reaches the first part of duodenum it produces a cap like shadow called *duodenal cap*. The size of the duodenal cap appears smaller than the size of the first part of the duodenum because of its obliquity. If the atmospheric temperature is reduced or person dislikes the taste of emulsion or fears the procedure for the examination will delay the emptying of the stomach.
- After few hours if a normal meal is given to the subject, the gastrocolic reflex is initiated and the barium meal reaches the beginning of colon. Otherwise it takes as early as 2–3 hours for stomach emptying or as late as 5–6 hours for emptying of the stomach. The duodenal cap appears as a triangular shadow with its base directed to the pyloric part of the stomach.
- The duodenum empties the emulsion fast and the 2nd, 3rd, and 4th parts of duodenum get filled with the contrast medium gradually. The shadows of mucosal folds can be appreciated.

BARIUM MEAL FOLLOW THROUGH (FIG. 13.3)

- As the emulsion is passing through the small intestine the radiographs are taken at intervals (1½–2 hrs) to see the shadows of the small intestine.
- The shadow of small intestine—jejunum and ileum—appears feathery and superimposed. This is due to the presence of circular folds and the villi that appear radiolucent.
- The emulsion reaches the ileocaecal junction about three hours after ingestion of the barium emulsion. The diameter of the small intestine shadow is about 1.4–2.5 cm depending upon the age of the individual. Emptying of small intestine takes about 12–14 hours. Then the emulsion reaches the large intestine.
- Once the emulsion reaches the large intestine and fills up the lumen, the haustrations can be appreciated with some amount of gas in the large intestine.
- The barium sulfate emulsion is completely evacuated from the intestine in 48–72 hours.

BARIUM ENEMA (FIG. 13.4)

In this procedure the barium emulsion is introduced through the rectum and the radiogram is taken within minutes. The haustrations or sacculations produce wider shadows with constrictions at intervals. The shadow of sigmoid colon appears as a loop which is overlapped by the shadow of the rectum. The flow of barium sulfate emulsion into the colon during the barium enema procedure is better observed by fluoroscopy.

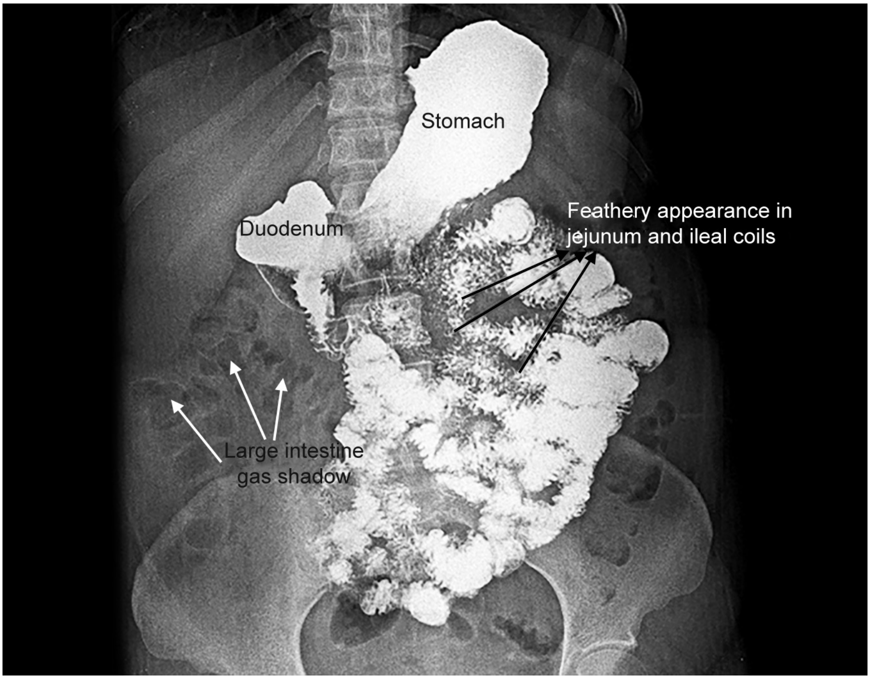


Fig. 13.3: Barium meal follow through. It is anteroposterior view of contrast radiograph of abdomen showing the shadows of small intestine.

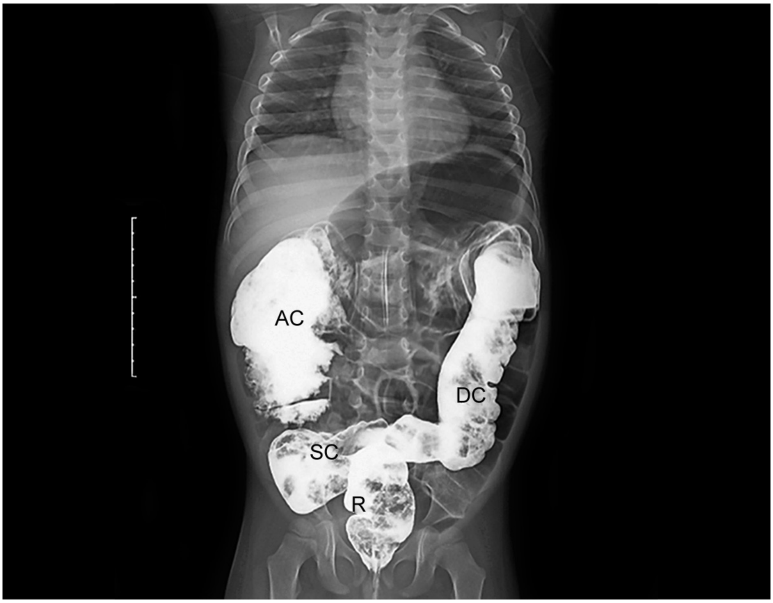


Fig. 13.4: Anteroposterior view of abdomen. It is a contrast radiograph called Barium enema done to visualize the shadow of large intestine.
(R: Rectum; SC: Sigmoid colon; DC: Descending colon; AC: Ascending colon).

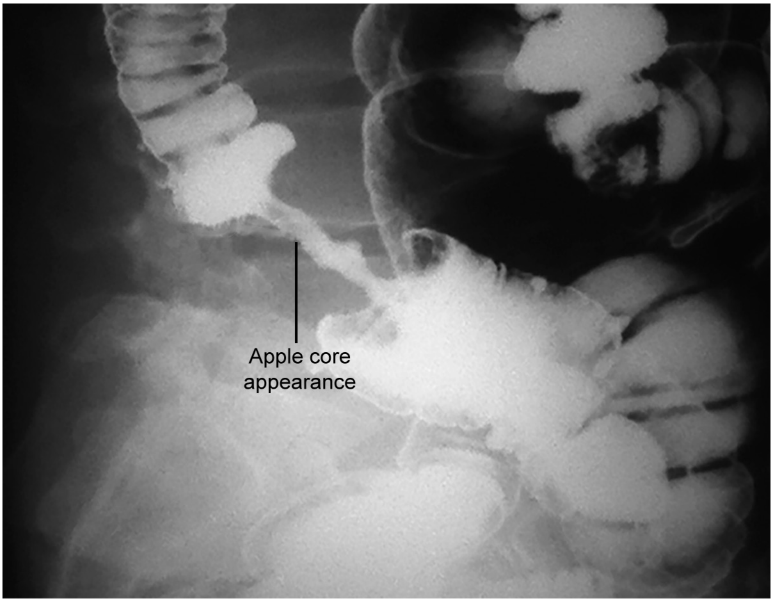


Fig. 13.5: Barium enema to visualize the large intestine. Filling defect resembles "apple core", indicating tumor projecting into the lumen.

Applied Anatomy

Barium meal is done in order to identify stomach ulcers or tumors. These will appear as filling defects when the contrast medium is swallowed and located in the stomach.

Barium meal follow-up helps to identify small intestinal diseases such as duodenal ulcers.

Barium enema is usually done to identify large intestine diseases like diverticulosis, carcinoma. Colon carcinoma is on the rise in incidence and this gives a characteristic apple core appearance in the contrast radiographs (Fig. 13.5).

CHOLECYSTOGRAPHY (FIG. 13.6)

It is a procedure for visualizing the gallbladder. The radiopaque dye in the form of tablets containing iopanoic acid (Telepaque) is administered orally. It is absorbed by the gut and goes to liver via portal vein and excreted from the liver in the bile. It is then stored in the gallbladder. In the gallbladder the water is absorbed and bile is concentrated which helps in increasing the contrast of the dye in the organ present.

Oral cholecystography is a painless, outpatient procedure. After the procedure the patient is advised to go home.

Preparing the Patient for the Procedure

1. Two days before the procedure, the person can have normal meal. Sometimes a diet rich in fat is preferred. This will stimulate the liver to produce more bile for fat digestion.
2. One day before the procedure a very low fat diet is given.

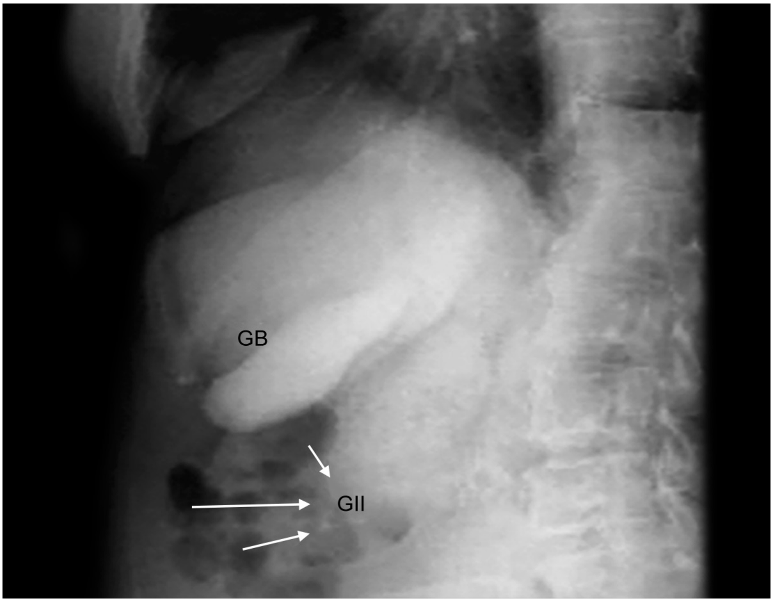


Fig. 13.6: Cholecystogram. Done to visualize the gallbladder.
(GB: Gallbladder; GII: Gas in the intestine).

3. The evening before the procedure the radiopaque dye in the form of pill (tablet) is given (totally six pills are given). One tablet per hour with enough water.
4. Nothing is to be eaten once the pills are given.
5. On the morning of the procedure—nil orally.
6. Enema may be given to prevent the shadows of gas and intestinal contents to overlap the shadow of gallbladder.
7. Then the radiograph is taken to visualize the gallbladder.
8. This is followed by a fat rich drink to be given to the person undergoing the procedure to stimulate the gallbladder to release bile.

Few people may experience pain in stomach (stomach cramping) or diarrhea. Some are allergic to the dye used and may experience itching, rash, and feeling of nausea. If associated with breathing difficulty and swelling of the face, then immediately the patient should be given proper medication to prevent allergic reaction.

This procedure is contra indicated in pregnancy.

Applied Anatomy

About 90% of the gallstones appear radiotranslucent on an opaque background where as only 10% of gallstones mislead as they are radiopaque.

The shadows of congenitally abnormal gallbladder, polyps, malignancy can be detected by this procedure.

Nowadays computed tomography is preferred over the oral cholecystography. Intravenous cholecystography is also done to study the blood vessels of the gallbladder. This procedure is called cholangiography.

PYELOGRAPHY

It is a procedure in which the contrast material is introduced into the urinary system to study the urinary organs—kidneys (K), ureters (U), and urinary bladder (B).

It consists of two methods:

1. Intravenous pyelography or descending pyelography or excretory urography (Fig. 13.7).
2. Retrograde/ascending pyelography (Fig. 13.8).

1. ***Intravenous pyelography***: Also called descending pyelography or excretory urography. In this procedure the dye is injected into any superficial vein of the limbs and the dye is excreted via the urinary tract. Thus the excreted dye appears in the urinary system and causes the shadow.

Procedure

- A radiopaque dye (urografin) is injected into the median cubital vein.
- The radiopaque substance enters the blood stream and reaches the heart, pulmonary circulation, back to heart and then to kidney for excretion.
- Radiographs are taken at intervals to assess the level of dye with urine and its filling into the hollow part of the urinary system.
- Immediately after the contrast medium is administered the dye appears in the cortex of the kidneys as "renal blush".
- The radiographs are taken at 3 min, 5–6 min, at 9 min and 15 min after the dye has been introduced into the superficial veins of the arm.
- Between 3 and 5 min the dye appears in the calyces.
- Around 9–14 min the dye starts entering into the ureters and into the urinary bladder.
- After the emptying of urinary bladder another radiograph is taken to visualize the urinary bladder for residual urine.
- The contour of kidneys are appreciated, shadows of calyces—both major and minor—are seen as cup like shadows.

Routine excretory urogram (Fig. 13.7): It is a procedure done when there is an unexplained microscopic hematuria or in case of tumor of kidney. This should be done after the plain radiograph of abdomen is done to visualize the renal area. Sometimes a compression is applied to the lower abdomen which increases the distension in the upper renal part. But compression is contra indicated in case of obstruction.

Pyelography is done in cases of emergency like the renal colic or macroscopic hematuria or renal calculi without any obstruction. Patients have to be admitted in case of renal calculi or in case of obstruction for further treatment.

In this emergency procedure a plain radiograph of abdomen is taken. About 50 mL of the contrast medium is injected intravenously. A delayed abdominal radiograph is taken after about 15 min after the dye has been injected. Then radiographs are taken 30 min, 1 hr, 2 hrs, 4 hrs after micturition. This will help the radiologist to see the level of obstruction.

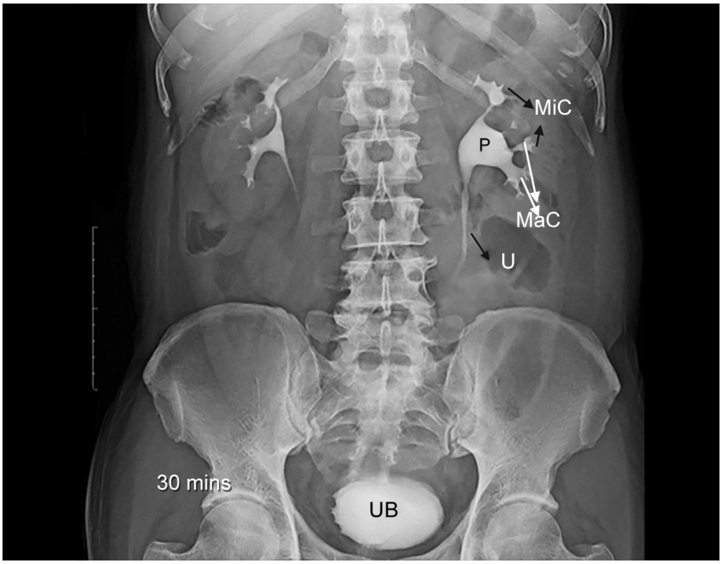


Fig. 13.7: Excretory urogram (descending pyelogram). Done to visualize the shadows of kidney, ureter, and urinary bladder.
(MiC: Minor calyces; MaC: Major calyces; P: Pelvis of kidney; U: Ureter; UB: Urinary bladder).

What to See in Kidney, Ureter, and Urinary Bladder (KUB)

***Kidneys*:** The total number, regular appearance with a smooth contour, the position, size and rate of filtration in each kidney.

***Ureters*:** Tubular appearance, smooth outline, the size, position and the rate of flow of the radiopaque dye. The ureters are normally visualized near the tips of the transverse processes of lumbar vertebrae. The constrictions can be seen at the commencement (pelvi ureteric junction), at pelvic brim (pelvic inlet), and at termination.

***Urinary bladder*:** Smooth appearance, placed just above the pubic region. Smooth appearence after complete voiding of urine.

***Contraindications*:** If the person is on Metformin for a long time, then the Metformin has to be stopped 48 hours before and after the procedure as the dye causes reaction with Metformin.

***Retrograde pyelography or ascending pyelography (Fig. 13.8)*:** In this procedure the dye is introduced into the urinary bladder or the ureters to enter into the kidneys. Thus, the dye ascends from ureters to kidneys (retrograde). This procedure is conducted to see the filling defects which are caused either by calculi or tumors. It is also indicated when there is renal disease, allergy to the contrast medium as it is injected into the blood.

***Contraindications*:** If there is infected urine, pregnancy, or allergy to the contract medium used.

Fig. 13.8: Ascending pyelography. Note the catheter in the urinary bladder directed toward the ureter.

***The procedure*:** A small tube is introduced via the urethra into the urinary bladder. Then dye is introduced into the ureters by passing the tube into the ureteric opening. Dynamic radiography or fluoroscopy is done to visualize the kidney, ureter, and urinary bladder (KUB). This procedure has to be done safely under general anesthesia of local anesthesia.

- Pyelography detects pelvi ureteric and vesicoureteric constrictions.
- It is also diagnostic in hydronephrosis where there is dilatation of the conducting pathway of the kidney (calyces to ureters). Here the calyces appear dumbbell shaped (Fig. 13.9).
- Polycystic kidney can also detected.
- Filling defects in the urinary bladder may suggest ulcers/polyps/carcinomas.

HYSTEROSALPINGOGRAPHY (FIG. 13.10)

A **hysterosalpingogram** (HSG) is a procedure in which there is radiological visualization of uterus and fallopian tubes after introducing radiopaque dye through vagina.

This is done to study the anatomy of the uterine cavity, polyps, growths, adhesions, foreign bodies, anatomy of uterine tubes and patency of the uterine tubes in sterile (infertile) women.

In this procedure a thin tube is introduced in to the cervical canal through vagina and the dye is introduced. Then radiographs are taken as the dye passes into the uterus and Fallopian tubes. The movement of the dye can be taken by fluoroscopy method also.

The dye spills in to the peritoneal cavity if there is patency of the Fallopian tubes.

This procedure is *contraindicated* when there is pregnancy, allergy to the radiopaque dye, etc.

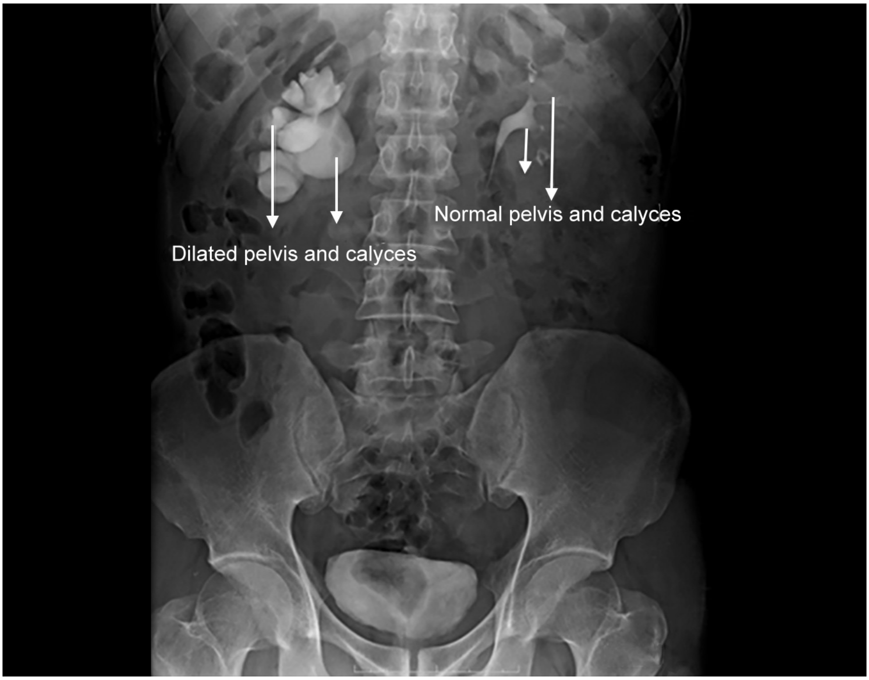


Fig. 13.9: Descending pyelography shows dilated pelvis and calyces on one side indicating hydronephrosis whereas the other side is normal.

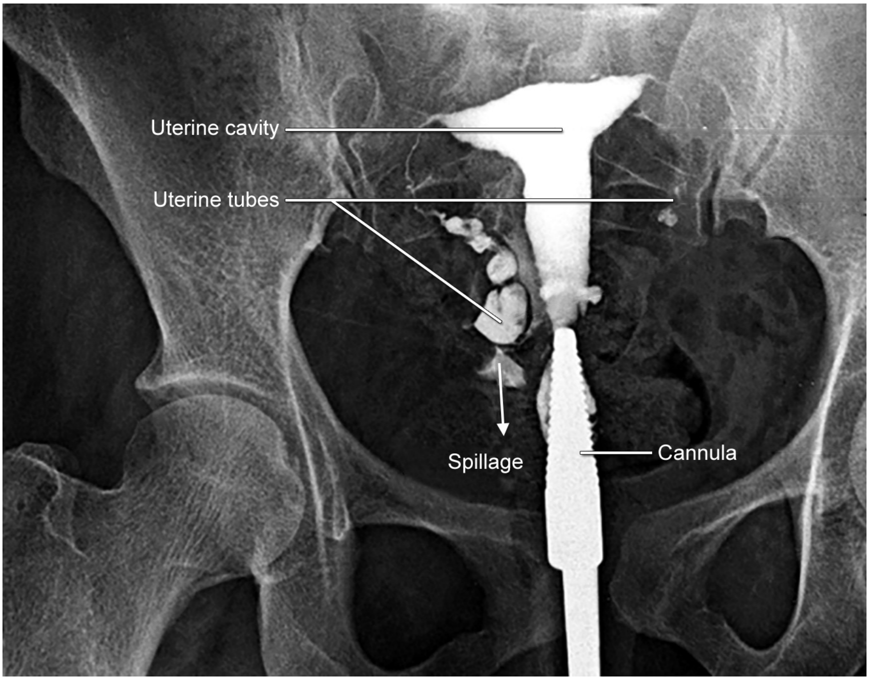


Fig. 13.10: Hysterosalpingography done to visualize the uterine cavity and patency of uterine tubes.

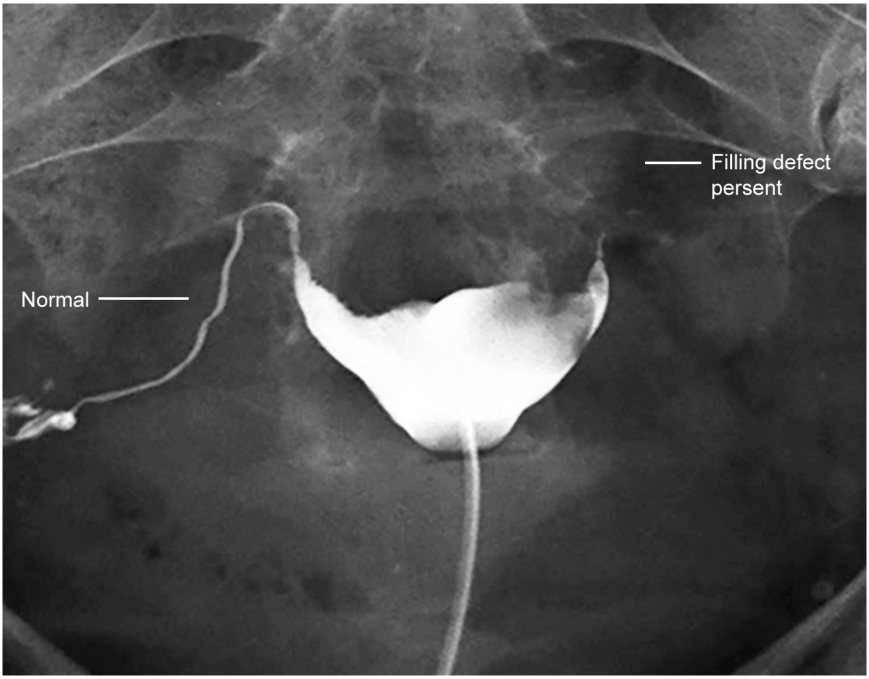


Fig. 13.11: Hysterosalpingography—filling defect.

Applied Anatomy

Hysterosalpingogram is most cost effective in detecting fallopian tube blocks.

It also detects congenital anomalies like bicornuate uterus, didelphys, septate and arcuate uterus, etc.

It is routinely to look for patency of the uterus and the uterine tubes which is indicated by spillage of the contrast into the pelvic cavity (Fig. 13.11).

Radiology of Head and Neck

14

The plain radiographs of head and neck show the radiopaque shadows of skull bones, mandible, hyoid and ossified laryngeal cartilages if any and cervical vertebrae. Radiolucent shadows of air filled cavities and tubes are seen, e.g. paranasal air sinuses, mastoid air cells, oral cavity, pharynx, laryngeal cavity, and trachea. The greyish shadows indicate soft tissues which include muscles, tendons, ligaments, vessels, and nerves. The soft tissue shadows cannot be differentiated in plain radiographs.

The skulls is made up of many small, flat, and irregular bones which articulate with one another at various types of fibrous joints especially at the sutures. In young skulls the sutures can be appreciated as zigzag dark lines.

VIEWS

The radiographs of head and neck are taken in anteroposterior, posteroanterior, lateral (right lateral or left lateral), superior (submentovertical), anterior oblique, posterior oblique, and lateral oblique views.

POSTEROANTERIOR VIEW (FIG. 14.1)

In this view, the forehead of the individual to be radiographed should face the film with orbitomeatal plane lying perpendicular to the film. The coronal suture, sagittal suture and part of lambdoid suture can be seen in the calvaria shadow. The inner and outer tables and the diploe are also visualized. **Depressions of 6 to 8 mm diameter** can be seen in a few radiographs which are caused by **arachnoid granulations**. The other features which can be seen are as follows:

a. Shadows of orbits.
b. The frontal, ethmoid, sphenoid, and maxillary air sinuses.
c. The opaque shadows of greater and lesser wings of sphenoid.
d. Inferolaterally, the shadows of mastoid process and air cells.
e. Dense triangular radiopaque shadow of petrous part of temporal bone.
f. The mandibular condyles make a shadow close to the petrous part of temporal bone.
g. The upper and lower teeth produce dense radiopaque shadow.
h. The shadows of nasal septum, conchae, and nasal cavities.
i. In a slightly tilted view, the odontoid process of axis vertebra can be visualized.
j. In children between 1½ and 2 years the anterior fontanelle makes radiolucent shadow.

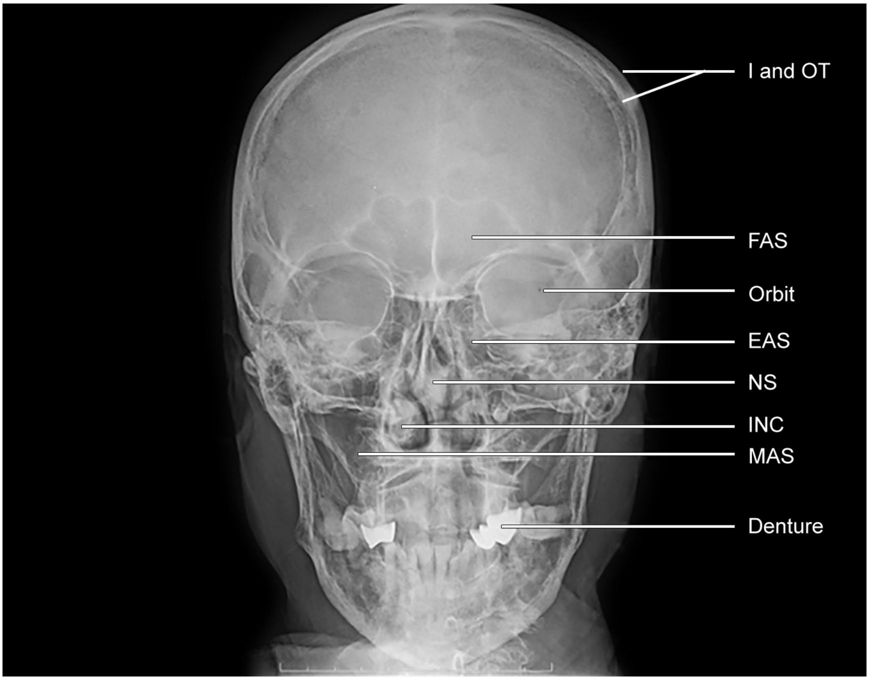


Fig. 14.1: Plain radiograph of head, PA view.
(I and OT: Inner and outer tables of skull vault; FAS: Frontal air sinus; EAS: Ethmoidal air sinus; NS: Nasal septum; INC: Inferior nasal concha; MAS: Maxillary air sinus).

ANTEROPOSTERIOR VIEW

It is taken with back of the head facing the radiographic film and the orbitomeatal plane lying perpendicular to the film. The features which are visualized clearly are as follows:

a. The lambdoid suture, occipital bone foramen magnum, dorsum sellae, posterior clinoid processes, mastoid air cells, petrous part of temporal bone.
b. Calcified choroid plexus, pineal gland with brain sand may be seen in radiographs of old age group.
c. The shadows of emissary vein foramina and arachnoid granulations.
d. The condyles of mandible.

LATERAL VIEW (FIGS. 14.2 AND 14.3)

In this view, one side of the head is toward the film and the other side to the tube. The orbitomeatal plane lying parallel to the film and interpupillary line horizontal and perpendicular to the orbitomeatal plane. For visualization of the entire skull the X-ray beam should be **1 cm above the orbitomeatal line** and 2 to 2.5 cm anterior to the external acoustic meatus.

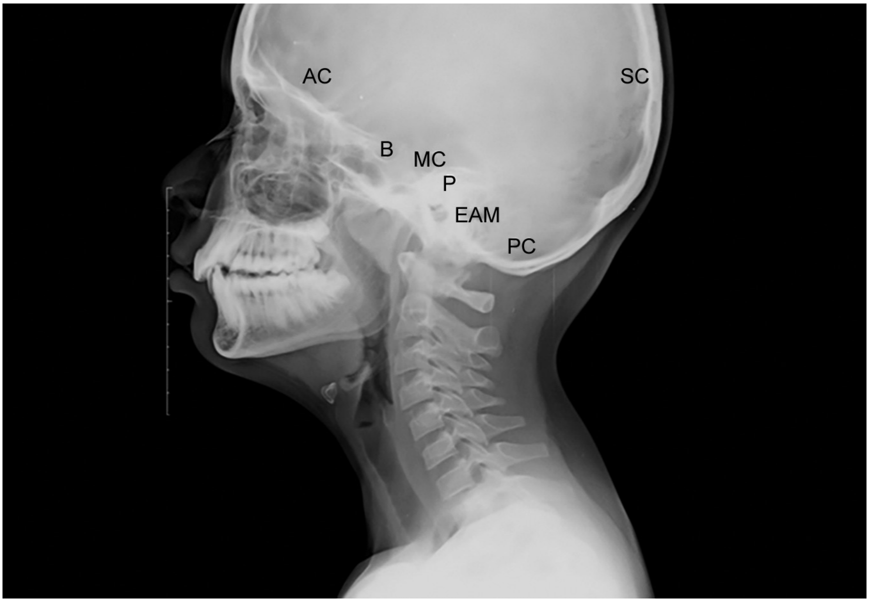
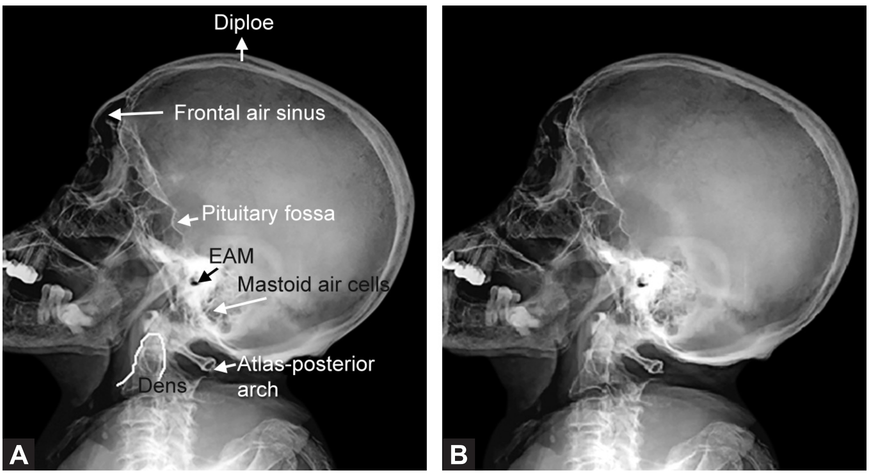


Fig. 14.2: Plain radiograph of head and neck, lateral view.
(AC: Anterior cranial fossa; B: Sella turcica; MC: Middle cranial fossa; P: Petrous part of temporal bones; EAM: External accoustic meatus; PC: Posterior cranial fossa; SC: Skull cap).



Figs. 14.3A and B: Plain radiograph of head and neck in lateral view with neck extended. (A) Labeled diagram and also Dens has been outlined; (B) Unlabeled and without markings.
(EAM: External accoustic meatus).

- The skull cap presents outer and inner tables [compact part of flat bones (Fig. 14.1)] with **diploe** (spongy or cancellous part of flat skull bones). The shadows of tables appear radiopaque and the diploe appears trabeculated. The sutures appear as serrated or zigzag radiolucent lines. Parts of coronal and lambdoid sutures can be seen clearly in young

skulls and lambdoid suture can be seen in old age also. **Vascular impressions** can be appreciated on the inner table which is caused by the **middle meningeal vessels** which are seen extending toward the coronal and lambdoid sutures in upward direction. Close to the lambdoid suture, horizontally curved radiolucent shadow is seen which is caused by transverse dural venous sinus.

- In sharp images of young skulls the radiolucent shadows of cerebral gyri can be seen.
- The arachnoid granulations produce shadows which are seen as notches or indentations on the inner table of skull vault, more prominent in older skulls.
- External ear produces a dense shadow in the posterior part of skull.
- The **frontal air sinus** of one side is seen as **triangular or conical radiolucent shadow** in the anterior part of the skull with its apex upwards. Here the shadows of inner and outer tables are separated by the shadow of the frontal air sinus.
- **Base of the skull:**
  - The **floor of the cranial fossae** which are arranged like **steps**. The anterior part is at a higher position and separates the anterior cranial fossa with that of the orbit.
  - The posterior end of the floor of the anterior cranial fossa is pointed and this is caused by the anterior clinoid process.
  - When traced posteriorly the middle cranial fossa is seen which presents a concavity called shadow of **sella turcica (Figs. 14.3A and B)**. The posterior wall of sella turcica is the dorsum sellae. The upper border of dorsum sellae presents posterior clinoid process, one on each side.
  - The anterior and posterior clinoid processes are sometimes connected by ossified interclinoid ligament that appears as a bridge on sella turcica.
  - The anterior and posterior walls of dorsum sellae meet at posterior clinoid process. Sometimes both walls fuse and form a single, thin layer. Absence of clear line of the anterior wall of dorsum sellae near the base is the first sign of pathological rise in the intracranial pressure caused by a tumor. The direct pressure from the tumor causes the erosion of dorsum sellae and posterior clinoid processes and compression of posterior clinoid processes can occur in case of **3rd ventricular dilatation as in hydrocephalus**.
  - Posterior to the dorsum sellae there is a **triangular, dense, radiopaque shadow** of petrous part of temporal bone. In the middle of the petrous temporal shadow there is a small, circular, radiolucent shadow caused by air in the external acoustic meatus.
  - Behind the posterior vertical border of petrous temporal shadow there is a **honey comb** like shadow caused by the **mastoid air cells**.
  - Below the mastoid air cells shadow and posterior cranial fossa there is a superimposed radiopaque shadow of first cervical vertebra. In the old age skulls the shadow of external occipital protuberance is seen.

SUPERIOR VIEW

In this view the film is facing the top of the head, with orbitomeatal line lying parallel to the film. Rays pass horizontally anteroposteriorly below the level of chin. In this view, the following shadows are seen:

- Mandibular shadow with teeth, maxillary air sinuses with prominent posterior walls, nasal septum, nasal cavities, sphenoidal air sinuses, ethmoidal air sinuses, foramina ovale and spinosum, basisphenoid, petrous temporal bones, condyles of mandible are seen.
- In the midline, behind basisphenoid, the anterior arch of atlas, odontoid process of axis vertebra, foramen magnum which is limited posteriorly by posterior arch of atlas.
- Behind the shadow of petrous temporal bone, lateral to odontoid process of axis the mastoid air cells are seen.

Lateral oblique view and anterior or posterior oblique views are taken to visualize the shadows of **paranasal air sinuses, mastoid air ells, mastoid antrum, temporomandibular joint, some dural venous sinuses, orbital margins,** etc.

WATERS VIEW (FIG. 14.4)

It is also called **occipitomeatal view**. In this view the beam is transmitted at **45° angulation to the orbitomeatal plane**. The rays pass at right angles to the radiographic plate. This view is taken to **visualize the paranasal air** sinuses especially the maxillary air sinus. Shadows of other paranasal air sinuses, orbits, odontoid process of axis vertebra just below the symphysis menti, mandible, upper and lower teeth, nasal cavities, nasal septum, zygomatic bones, zygomatic arches and petrous temporal bone are seen.

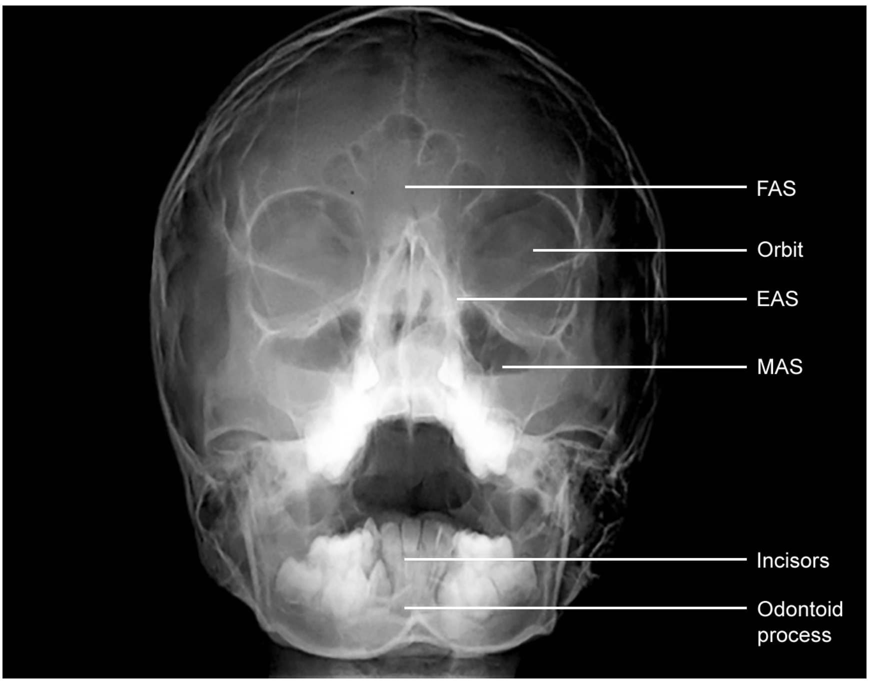


Fig. 14.4: Plain radiograph of head region in Waters view or orbitomeatal view. This is taken for the para nasal air sinuses.
(FAS: Anterior cranial fossa; EAS: Sella turcica; MAS: Middle cranial fossa).

RADIOLOGY OF NECK

Posterior view**:** This view is taken to study the **cervical part of vertebral column, atlanto occipital joint, atlanto axial joint, intervertebral disk spaces, air-filled spaces like oral cavity, pharynx, larynx, trachea, etc**. Hyoid bone and ossified laryngeal cartilages also are seen in this view. The shadows of bones appear as radiopaque and that of air-filled spaces appear radiolucent.

Lateral view (Fig. 14.5)**:** It is the better view to see cervical part of vertebral column, atlanto occipital joint, atlanto axial joint, intervertebral disk spaces, air-filled spaces like oral cavity, pharynx, larynx, trachea, hyoid bone and ossified laryngeal cartilages. The anterior and posterior arches of atlas vertebra can be appreciated well. The **shadow of anterior arch is superimposed on the odontoid process of axis vertebra**. The shadow of posterior arch of atlas vertebra lies immediately below that of occipital bone. The posterior part of axis vertebral shadow appears prominent. The bodies of 2nd to 7th cervical vertebrae with the disk spaces between them, the spinous processes of 2nd to 7th cervical vertebrae are visualized. The shadow of **spine of the 7th cervical vertebra** appears longer and distinct when the neck is flexed. In the upper part of the neck shadow the lower jaw (body of mandible), temporomandibular joint (in some radiographs), teeth are visualized. Air present in the mouth, pharynx, larynx, and trachea are seen as radiolucent shadows. Between the shadows of trachea and vertebral bodies the soft tissue shadow of esophagus and prevertebral muscles and fascia are seen. **Ossified laryngeal cartilages and calcified tracheal rings are seen below the hyoid bone shadow**. Hyoid bone is seen just below the mandibular shadow.

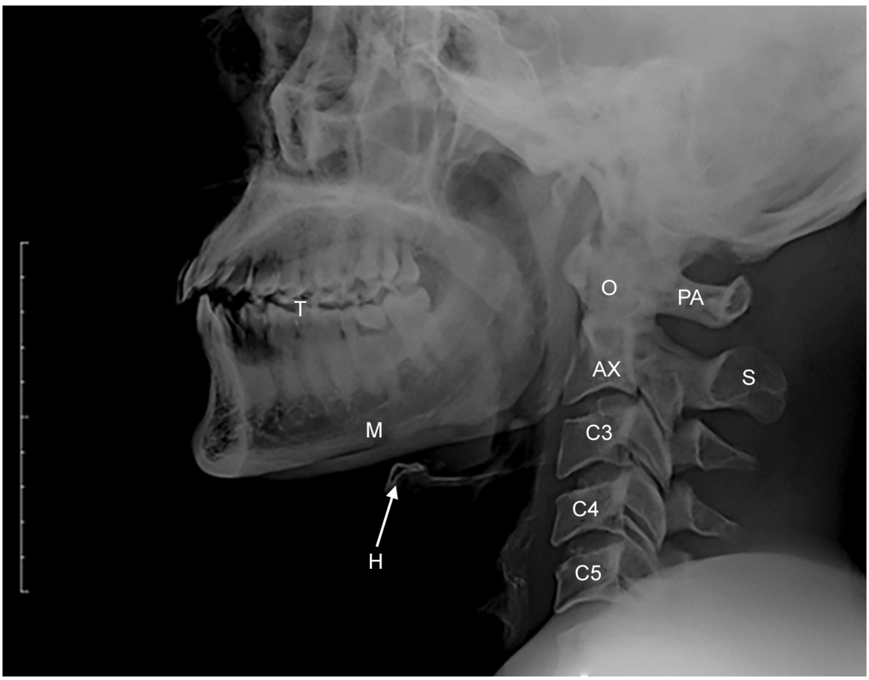
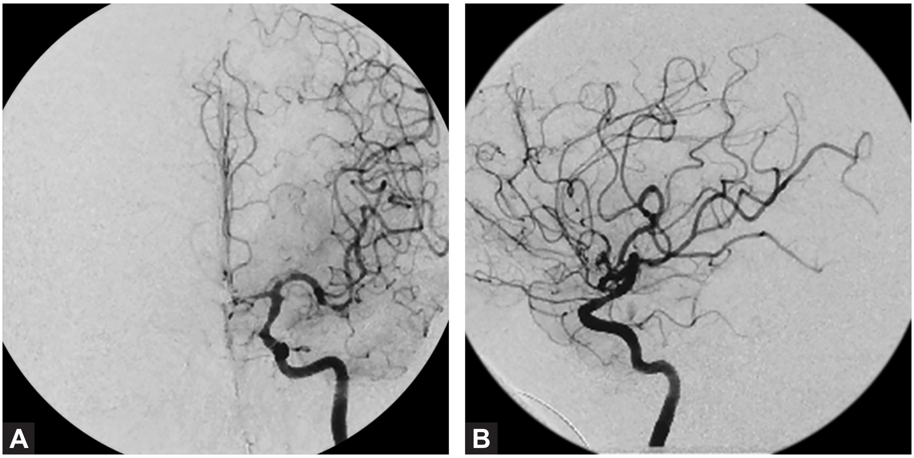


Fig. 14.5: Plain radiograph of neck, lateral view.
(O: Odontoid process; PA: Posterior arch of atlas; Ax: Body of axis vertebra; S: Spinous process of axis vertebra; C3–C5: Bodies of C3, C4, and C5 vertebrae; T: Teeth; M: Mandible; H: Hyoid bone).



Figs. 14.6A and B: Carotid artery angiogram. Contrast dye has been introduced into the carotid artery of one side. (A) Anteroposterior view; (B) Lateral view.

CAROTID ANGIOGRAPHY (FIGS. 14.6A AND B)

It is a procedure in which a catheter is introduced in to a superficial vessel in upper or lower limb **(radial artery or femoral artery)** and guiding it to the level of carotid arteries with the help of radiographic guide and then a contrast material is introduced into the internal carotid arteries through a catheter and radiographs are taken. It is a painless, but invasive procedure used to determine the blockage, narrowing of the arterial lumen and for placing the stent if there is narrowing.

The instructions for this procedure are like any other invasive procedures—allergy for the dye used, evaluation of cardiovascular system, respiratory system, renal system, and nervous system is to be done. Patient is asked to drink plenty of water for good hydration and excretion of the dye before the procedure. **Three radiographs** taken immediately and series of radiographs are taken subsequently or a **movie** is recorded to see the flow of the radiopaque dye.

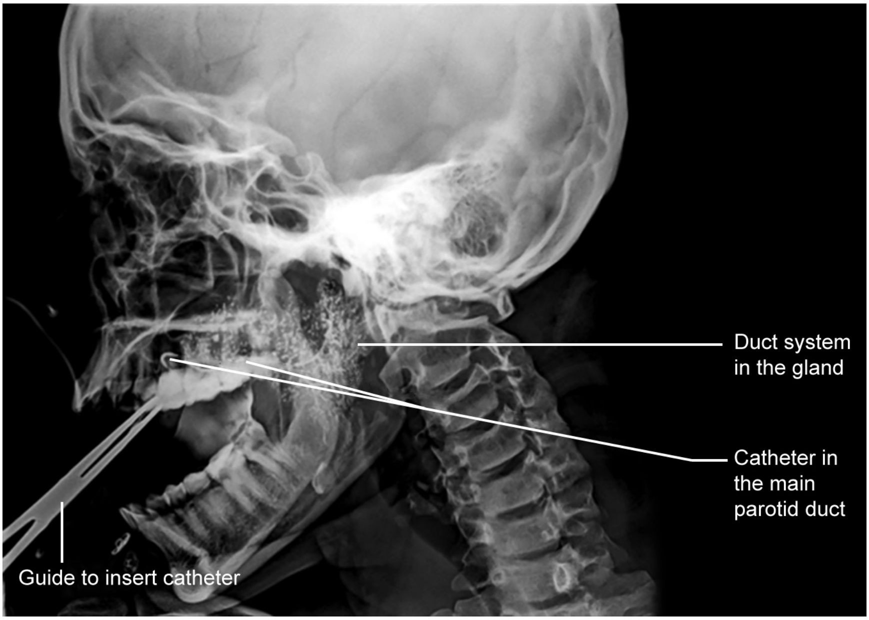
SIALOGRAPHY (FIG. 14.7)

It is a procedure, in which a radiographic examination of **salivary ducts** and **salivary glands** is made after introducing a radiopaque dye in to the ducts of salivary glands to be examined.

Procedure

Initially a plane radiograph of face/parotid/submandibular region is taken to rule out any radiopaque stones in the salivary glands.

A fine cannula is inserted in to the opening of the duct using a lacrimal duct probe to guide the cannula. Then a radiopaque dye is injected (preferably water soluble) into the duct through the cannula. Then series of radiographs are taken, preferably in lateral view,



Figs. 14.7: Parotid sialogram.

to assess the flow of the dye in to the duct system and in to the glandular tissue. If there is a stone or growth causing obstruction this will cause filling defect in the duct system. There can be dilatation of the duct system of salivary glands. In case of atrophy of the salivary acini the radiograph appears as **"pruning of the tree."**

Indications

- In parotid swellings to diagnose obstruction caused by stone of tumor.
- To assess the branching pattern of the duct system.
- To assess the functioning of the salivary gland.

Contra Indications

- Anteriorly placed calculi in the duct system
- Allergy to the contrast medium
- In patients with thyroid function tests
- In case of acute infection of salivary glands.

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